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CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

SPECIAL FEATURES

Detecting elements and how to classify them
Sira's Dr A. J. MADDOCK shows how a logical and systematic approach can make life easier for the user 84

Digital inclinometer for automatic incidence setting
G. P. TONKIN of Bristol Aircraft describes an example of the integration of the analogue with the digital in a control system 88

Industrial timing problems
You can cut your costs by adapting standard timers for special purposes, says J. K. CHUCHLA of Electrical Remote Control 92

Network theory at Cranfield
A concise report of the recent symposium, specially written by J. W. HEAD of the B.B.C. Research Department 96

A slope method of approximation to the describing function
Graphical methods seems to be the proper ones for non-linear problems, argues B. L. DEEKSHATULU of the Indian Institute of Science, Bangalore 99

Production control and machine loading in a jobbing shop
Concluding his two-stage-planning proposal, S. DEMCZYNSKI of de Havilland's says that steps to greater efficiency demand the use of a computer 102

Control on the Continent
This is the first news-letter from Control's *Special Correspondents on the European mainland, Dr L. PUN and Mr SANJOY MITTER of the Battelle Memorial Institute, Geneva* 114

Title page and Index to Volume 4 facing p. 198

REGULAR FEATURES

Leader : Seek and ye may find 79

Viewpoint : More fact—less intuition *by John Ryan* 83

Data sheet 25 : Effects of adjacent piping arrangements on control valve characteristics *by G. F. Brockett and W. J. L. Kennedy* 105

Ideas applied . . . *to* new hydraulic drive—brightness control by s.c.r.—generation of vibration—moisture content of paper. 110

Look at America: A.S.M.E. textile engineering conference—Process dynamics—Digital speed regulation 116

Control in action : A water-level control system *by J. L. Leonard and H. Evenden* —Induction heating at Vauxhall's—Testing transistors automatically—Wandsworth logs refuse-data 118

Looking ahead 4 | News round-up 123 | New for the user 130
Letters to the Editor 80 | People in control 126 | Publications received 137
Pick-off 109 | Authors in *Control* 129 | Book reviews 138

LOOKING FOR A JOB? Control *carries the best jobs in instrument and control engineering.* **SEE PAGE 196 AND ONWARDS**

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LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.A.C., British Conference on Automation and Computation. B.C.S., British Computer Society. Brit.I.R.E., British Institution of Radio Engineers. I.C.E., Institution of Civil Engineers. I.Chem.E., Institution of Chemical Engineers. I.E.E., Institution of Electrical Engineers. I.Mech.E., Institution of Mechanical Engineers. I.Prod.E., Institution of Production Engineers. I.S.A., Instrument Society of America. R.Ae.S., Royal Aeronautical Society. S.B.A.C., Society of British Aircraft Constructors. S.I.T., Society of Instrument Technology.

TUESDAY 12 DECEMBER
Half-day meeting on *Strain gauges*. Details: The Institute of Physics and The Physical Society, 47 Belgrave Sq., S.W.1.

Design, application and selection of automatic control valves by P. Stone. Stanley Palace, Watergate St, Chester. (*S.I.T.*)

WEDNESDAY 13 DECEMBER
Application of complex plane methods to system design by P. K. M'Pherson. (*S.I.T.*)

Nuclear power-station instrumentation by M. W. Jervis. 7.30 p.m. The Walker Art Gallery, Liverpool. (*Brit.I.R.E.*)

Analysis of overall stability of multi-machine power systems by J. G. Miles. 6 p.m. Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow. (*I.E.E.*)

TUESDAY 19 DECEMBER
Lecture on *The use of controllable semiconductor rectifiers in machine control* by K. G. King. (*I.E.E.*)

TUESDAY 9 JANUARY 1962
Lecture on *A linear transducer of high accuracy* by P. C. F. Wolfendale. (*I.E.E.*)

TUESDAY 9—THURSDAY 11 JANUARY 1962
The 8th National Symposium on *Reliability and quality control in electronics*. Washington, D.C., U.S.A. Details: R. Brewer, Hirst Research Centre, G.E.C. Ltd, Wembley, Middx.

WEDNESDAY 10 JANUARY 1962
Automatic assessment of transistor life-test data by K. Walker and M. J. Crouch. 7 p.m. Southampton University. (*Brit.I.R.E.*)

Lecture on *Automatic control of machines for assembling mechanical components* by A. V. Hemingway and R. L. Dressler. 6.30 p.m. Brighton Technical College. (*I.E.E.*)

The generation and control of humidity by K. Davis, Imperial College. Details: The Society of Environmental Engineers, Suite 7, 167 Victoria St, S.W.1.

A review of digital computer control applications by E. M. Grabbe. (*S.I.T.*)

THURSDAY 11 JANUARY 1962
Digital telemetry by J. B. Richardson. 7 p.m. Royal Society of Arts. Details: The Radar and Electronics Association, 43 Grove Park Rd, Chiswick, W.4.

MONDAY 15—FRIDAY 19 JANUARY 1962
The 46th Exhibition of Scientific Instruments and Apparatus. Royal Horticultural Society's Halls. Details: The Institute of Physics and The Physical Society, 47 Belgrave Sq., S.W.1.

TUESDAY 16 JANUARY 1962
Lecture on *Automatic control of machines for assembling mechanical components by* A. V. Hemingway and R. L. Dressler. 6.15 p.m. Engineers Club, Albert Sq., Manchester. (*I.E.E.*)

WEDNESDAY 17 JANUARY 1962
Verdan—a miniature computer for airborne use by P. B. Rayner and S. Morleigh. (*Brit.I.R.E.*)

WEDNESDAY 17—THURSDAY 18 JANUARY 1962
A symposium on *Electronic aids to banking*, under the aegis of B.C.A.C. Details and registration forms: I.E.E.

MONDAY 22 JANUARY 1962
'Exposition meeting' on *Recent developments in automatic boiler control practice*. Details: R. J. Redding, 66 The Drive, Isleworth, Middx. (*See also* Control, *July*, *p.* 122). (*S.I.T.*)

A lecture on *Air Traffic control* by E. Eastwood and B. J. O'Kane. (*I.E.E.*)

TUESDAY 23 JANUARY 1962
Lecture on *Power supply control systems* by P. F. Gunning. (*I.E.E.*)

THURSDAY 25 JANUARY 1962
Recent developments in non-destructive testing by R. S. Sharpe. 7 p.m. Bristol College of Science and Technology. Details: The Institute of Physics and The Physical Society, 47 Belgrave Sq., London, S.W.1.

MONDAY 29 JANUARY 1962
Informal discussion on *Teaching of automatic control*. (*I.Mech.E.*)

FRIDAY 16—TUESDAY 20 FEBRUARY 1962
Salon International des Composants Electroniques. Parc des Expositions, Porte de Versailles. Details: S.D.S.A., 23 rue de Lubeck, Paris 16e, France.

MONDAY 19—FRIDAY 23 FEBRUARY 1962
International seminar on *Automatic control in iron and steel industry*. Palais des Congrès, Brussels. Details: Sécrétariat Permanent de l'Institut Belge de Régulation et d'Automatisme, 98 chaussée de Charleroi, Brussels 6, Belgium.

MONDAY 26—WEDNESDAY 28 FEBRUARY 1962
A conference organized by a joint committee of the I.E.E. and the R.Ae.S. on *The importance of electricity in the control of aircraft*. Details: I.E.E.

WEDNESDAY 7 MARCH 1962
Control and operation of pneumatic furnaces by M. J. McInerney and H. Lewis. 7.30 p.m. John Leggett Grammar School, Scunthorpe. (*I.Chem.E.*)

TUESDAY 10—FRIDAY 13 APRIL 1962
Joint conference, Royal Dutch Inst. of Engrs. and S.I.T. Amsterdam, Holland. Six papers (10th and 13th): *Recent developments in physical methods of analysis; Problems of automation in process industries; Optical measuring techniques; Introduction of digital modules; Automation in mine shaft sinking; B.S.I.R.A.* Details: I. V. Idelson, Mullard Equipment Ltd., Manor Royal, Crawley, Sussex.

FRIDAY 13—THURSDAY 19 APRIL 1962
International Refrigeration Fair. Olympia. Details: International Refrigeration Fair, 2 Duraven St, W.1.

MONDAY 16—WEDNESDAY 18 APRIL 1962
The Second International Flight Test Instrumentation Symposium. College of Aeronautics, Cranfield. Details: M. A. Peary, The College of Aeronautics, Cranfield, Bletchley, Bucks.

TUESDAY 24—THURSDAY 26 APRIL 1962
International symposium on *The mathematical theory of automata*. New York, U.S.A. (Papers and abstracts by January 5, 1962.) Details: Symposium Committee, Polytechnic Institute of Brooklyn, 55 Johnson Street, Brooklyn, 1, N.Y., U.S.A.

WEDNESDAY 25 APRIL—FRIDAY 4 MAY 1962
Conférence Internationale des Arts Chimiques. Paris. Details: Maison de la Chimique, 28 bis rue Saint-Dominique, Paris 7e, France.

THURSDAY 26 APRIL 1962
'Exposition meeting' on *Self adaptive control systems*. Details and suggestions: R. H. Tizard, Whitterick, Ellesmere Rd, Weybridge, Surrey. (*See also* Control, *July*, *p.* 122). (*S.I.T.*)

MONDAY 30 APRIL—FRIDAY 4 MAY 1962
Second International Compressed Air and Hydraulics Exhibition. Olympia. Details: W. G. H. Chesher, St Richard's Ho., Eversholt St, N.W.1.

MONDAY 30 APRIL—SATURDAY 5 MAY 1962
The Ninth International Automobile Technical Congress, organized by the Fédération Internationale des Sociétés d'Ingénieurs des Techniques de l'Automobile. Details: F.I.S.I.T.A. Congress Secretariat, I.Mech.E. Automobile Div., 1 Birdcage Walk, S.W.1.

WEDNESDAY 2—FRIDAY 11 MAY 1962
Power Generation and Clean Air Equipment Exhibition, and The first British Exhibition of Space Research and Technology. Olympia. Details: British Interplanetary Society, 13 Bessborough Gdns, S.W.1.

TUESDAY 8—FRIDAY 18 MAY 1962
Mechanical Handling Exhibition. Earls Court. Details: H. A. Collman, Dorset Ho., Stamford St, S.E.1.

MONDAY 28 MAY—FRIDAY 1 JUNE 1962
Colloquium on *Modern computation techniques in industrial automatic control*. Paris. Details: A.F.R.A., 19 rue Blanche, Paris, 9e. (*See also* Control, *November*, *p.* 127)

MONDAY 28 MAY—SATURDAY 2 JUNE 1962
International Instruments, Electronics and Automation Exhibition. Olympia. Details: Industrial Exhibitions Ltd, 9 Argyll St, W.1.

THURSDAY 31 MAY—THURSDAY 7 JUNE 1962
International Television Conference. Institution building, London. (*I.E.E.*).

WEDNESDAY 20—TUESDAY 26 JUNE 1962
Third Congress of the European Federation of Chemical Engineering. Olympia. Details: The General Secretary, Society of Chemical Industry, 14 Belgrave Sq., S.W.1.

WEDNESDAY 20—SATURDAY 30 JUNE 1962
The Second Chemical and Petroleum Engineering Exhibition. Olympia. Details: Engineering in Britain, 34 Victoria St, S.W.1.

MONDAY 25—THURSDAY 28 JUNE 1962
The Fourth Congress of the Federation of European Petroleum Equipment Manufacturers. Church Hall, Westminister. Details: Council of British Manufacturers of Petroleum Equipment, 2 Princes Row, S.W.1.

MONDAY 3—SUNDAY 9 SEPTEMBER 1962
S.B.A.C. Flying Display and Exhibition. Farnborough. Details: S.B.A.C., 29 King St, St James's, London, S.W.1.

SEPTEMBER 1963
Second congress of the International Federation of Automatic Control. (Ifac). Basle, Switzerland. Details: papers, B.C.A.C., c/o I.E.E.; general inquiries, Dr-Ing. G. Ruppel, Prinz-Georg-Strasse 79, Düsseldorf, Germany.

DECEMBER 1961 VOL. 4 NO. 42 CONTROL

Seek and ye may find

CONTROL ENGINEERING is a dynamic, fully extended activity. Development and application, while pulling ahead at a tremendous rate, still stretch well to the rear of what is possible, for the labile forward fringe is itself obstructed by many encumbrances of a kind that could be cleared away. Some of these encumbrances have more than once been pointed out on this page: the lack of a common meeting ground for control engineers, to take one instance, and the inadequacies of communication and co-ordination. Our strictures have tended to be in general terms, but concrete examples are only too easy to find. One of them is the way in which literature is stored and handled.

There is no library in London where engineers and scientists may be sure to find all the usual technical periodicals and books. Many hours may be lost in hunting for just one reference, and this is unfortunately true of all the principal libraries in the capital. At the Science Library, for instance, one cannot take books off the shelf, but must complete a request-form and then wait for about half an hour, often to find that the reference is already out on loan. The Patent Office Library is good on periodicals, but seems to hold very few books. The British Museum Library restricts itself to British scientific publications. The University of London Library can be useful, but here again the essential book is frequently in the hands of another borrower.

A research worker, well known for his contributions in the field of automatic control, recently described some of his library experiences to us, and it is worth drawing public attention to these not untypical instances of frustration and wasted time. Wishing to trace a reference in the 1960 edition of Yourgrau and Mandelstam, he went to the Science Library. His request produced the 1955 edition after three-quarters of an hour, but this edition did not contain the reference. A further request for the 1960 edition spent twenty-five minutes in the administrative machinery but failed in spite of that—the book was out on loan. The Chemical Society had the 1956 edition; the British Museum Library had the 1956 edition; the University of London Library had the 1955 edition: and the desired reference was finally located in a bookshop. On another occasion the quarry was a 1926 copy of the *Zeitschrift für Angewandte Mathematik und Mechanik*. A search through the libraries was fruitless, and the British Union list revealed that there was only one copy in the whole of London, at the University College Library.

A short while ago there was a ten-day conference at Unesco headquarters in Paris (under the chairmanship of the British Museum's Principal Librarian), at which delegates from more than thirty countries discussed the problems of library cataloguing. One must hope that these deliberations were fruitful, because the present indexing methods can certainly be infuriating. For illustration, we need again draw only on the experience of our research-worker friend.

At the British Museum he failed altogether to find mention of the American Chemical Society, and discovered the Chemical Society indexed under:

> London III: Miscellaneous Institutions, Societies and other Bodies; Chemical Society.

Wanting the Proceedings of the Sixth Congrès du Froid, Buenos Aires, 1932, he tried *Congrès du Froid* at the Science Library but found no card. Then he tried *Buenos Aires, Congrès*, etc., all without success, and eventually the Library staff themselves concluded that they did not have the book. A copy was found at the Institute of Refrigeration, but our friend went back later to the Science Library for another check. There, at last, he tracked down this rather lovely index entry:

> Europe: Congrès International du Froid, Actes du VI^{ème} Congrès, Buenos Aires

and the only cross-reference was from *Congrès international* (there were no cross-references from *Congrès mondial* or like headings).

Experiences of this sort are particularly galling to control and systems engineers, who are vitally concerned with data handling and processing. There would appear to be a clear case for the application of automatic data processing to libraries, but, even before that, a great deal could be done to make existing services more useful to engineers and scientists.

LETTERS to the EDITOR

2D units

SIR: The recent controversy between advocates of different systems of units and also "Uncontrolled"'s puzzle of the dual character of mass as a source of gravitational attraction and as a resistance to acceleration (*Control*, September 1961, pg. 84 and 114) can be resolved by a system of units which may be termed the gravitational system and is based not on three but on two fundamental dimensions, namely length and time.

Although I have no illusions about the practical difficulties of introducing such a system, its explanation will perhaps help to eliminate certain misconceptions.

Going back to fundamentals, it must be understood that Newton's law of gravitation was derived from observations of the movements of celestial bodies, i.e. from measurements of displacements, distances and time intervals, and from evaluations, from these measurements, of derived quantities, such as velocities and accelerations. It was found that these movements are essentially functions of a property of each body which is inherent in it and which was called its mass and of variable distances between the bodies. The concept of force as the product of mass and acceleration does not constitute a law of nature but merely a definition of a quantity from basic observations of distances, displacements and time intervals.

If one states, therefore, the law of gravitation as $F = M_1M_2/D^2$ and the definition of force as $F = M_1.a$ these two statements can be used to define the dimensions of mass and force in terms of the basic dimensions of length and time.

Thus, by equating the r.h. sides of the above two equations dimensionally, the dimensions of mass and force can be determined as $M = L^3.T^{-2}$ and $F = L^4.T^{-4}$.

In a system of this description, the controversy between the *M L T* and *F L T* schools of thought becomes meaningless since both mass and force are derived from length and time. Also, the dual character of mass disappears since there is only one fundamental law, the law of gravitation, involved in these considerations whilst the "law" of acceleration is reduced to a mere definition of force as a product of mass and acceleration.

The conventional systems depend on the introduction of a constant of dimension $L^3M^{-1}T^{-2}$ into the law of gravitation for which there is neither a physical nor a logical justification but perhaps only one of the convenience of having a fundamental mass or force unit, a convenience which has to be paid for by confusions and misconceptions not easily eradicated even by "crystal clear" B.S. definitions.

Windsor K. GOITEIN

More computers

SIR: In the review of computers which appeared in your October issue, details were included of the I.B.M. 7070, 7074, 1620 and 1410 computers.

I feel that this list might be misleading without adding that these models were selected to represent certain scales of commercial and scientific computers respectively which are marketed by I.B.M. in this country. They in no way comprise a complete list.

In the introductory paragraphs to this survey, it is also stated that the I.B.M. Stretch and 7090 computers "have had to be excluded as they are not yet commercially available here". This is not the case. One Stretch is being delivered next year, and two 7090's are already installed in this country with others on order. This scale of computer is certainly available to any organization that has the work load that will justify it.

B. J. HARGREAVES

I.B.M. United Kingdom Ltd

● *Mr R. J. A. Paul, who compiled* Control *Survey No. 22 to which Mr Hargreaves refers, writes: 'Although I was aware that a 7090 was being installed in London, I had to infer that Stretch and the 7090 were not yet commercially available in this country because they were not included in the information provided by I.B.M.' We are pleased to hear that these interesting machines are indeed available over here, as well as other I.B.M. computers about which details were not provided for the* Control *Survey.*—EDITOR

Insert control equipment

SIR: We should like to draw your attention to the fact that our Company, Vactric Control Equipment Limited, has been abbreviated to Vactric under the Buyers Guide Classification Section.

We are anxious to stress that this should not be confused with Vactric Limited, with which Company we are in no way connected.

E. M. B. BINYON

Vactric Control Equipment Ltd

● *We are very sorry if we have unwittingly misled anybody by using this abbreviation. (For the benefit of readers who are not subscribers, perhaps we should point out that Mr Binyon is referring to the Industry Guide and Digest issue of* Control, *a copy of which is sent free to every subscriber. Copies of this annual reference book may also be purchased, and are obtainable from the Circulation Manager,* Control, *The Rowse Muir Building, 77–79 Charlotte Street, London, W.1, price £1 per copy.)*—EDITOR.

Correction: We apologize for an error in the presentation of *Electronic hybrid amplifiers for industrial temperature measurement* by R. J. Redding, p. 95 of *Control* for November 1961. The blocks for Figs. 2 and 4 were inadvertently interchanged.—EDITOR

VIEWPOINT

John Ryan, Director of the Metal Box Company Limited, suggests that the computer —properly used—can help managements to base decisions on . . .

MORE FACT— LESS INTUITION

The rapid growth in the size of industrial organizations and the increased complexity of their operations, the improvement in communications, the shrinkage of distance by air transport and the increasing degree of product specialization, have all combined in the last decade to present management with an increased load of responsibility, calling for new techniques. The earlier years of this century have seen the development of the art and science of management, and the emergence of new tools of management has provided the means for teaching practitioners and stimulating the improvement of their techniques.

Both in office and factory, mechanical aids have made procedures practicable which would otherwise have been impossible. Nevertheless, mechanical aids have brought in their train an increasing amount of paper work and figures, which, by its volume, has tended to reduce the usefulness of those aids, if only because they have overwhelmed their recipients. In self defence, the latter have been compelled to seek interpreters who can distil out the relevant factors which call for action. We have seen, as part of this background, the growth of functional specialists who have become essential, but who are always a potentially disruptive force to line authority.

The advocates of both centralization and decentralization have fought inconclusive battles, often without getting down to those fundamental issues which might (and probably would) have shown that both had a part to play. Decentralization, without previous centralization, is doomed to failure, just as centralization as an end in itself cannot succeed.

The use of statistics in market research and budget forecasting has shown that this 'language of size' is something which must be learned and does not come without study; there are still far too few top executives who are either fluent in its use or who understand its literature. This has meant that the mechanical instruments and their operators, progressive though the latter may have been, are rarely used to their full potential—one still finds relics of the quill-pen mentality in the use of intricate machines.

Nevertheless, whatever may have been the usefulness of our mechanical aids in the past, the arrival of the electronic computer is revolutionary. Computers are destined, in my view, to be recognized as the most powerful management tool yet developed. They can, if part of an intelligently designed system, offer management information that is vital in forming sound decisions: information which previously could never have been made available at the right moment, if at all.

However, the computer should not be confined merely to improving systems for narrowly defined operations. We must think in terms of total systems which integrate process, plant, and computer. The right approach can only come from an atmosphere of critical thinking and a minimum of routine.

As management becomes more complex, effective co-ordination between the various functions grows to be all-important, and the impact of independent decisions becomes more dangerous. In a large concern, few people combine experience in systems analysis with knowledge of specific parts of the company's procedures. The initiative for planning innovations must not be left to systems-analysis personnel alone; it must come from the co-ordination of a wide group of general practitioners, who can help to incorporate new techniques in day-to-day operations.

The electronic computer can provide an objective co-ordinated analysis, in which the effect of conflicting views can be pre-measured and predicted, so that final decisions can be based upon the maximum of fact and the minimum of intuition.

John Ryan

Bearings are easily lost in the welter of scientific, technical and commercial information. A clear head and good charts are vital

Detecting elements
and how to classify them

by **A. J. MADDOCK** D.Sc., F.Inst.P., M.I.E.E., *British Scientific Instrument Research Association*

IN ANY SYSTEM EMPLOYING INSTRUMENTS FOR EITHER measurement or control, it is necessary to provide, for each, a device for sensing a particular state in the system to provide a suitable output for actuating the measuring or controlling apparatus. Such a device is called a sensing, primary, or detecting element: it is this latter term which we shall use; according to the B.S.I. glossary (*1*) it is ' that part of the measuring unit which responds directly to the value of the controlled condition '.

Another frequent term is ' transducer ': as used in the instrument world this term certainly refers to a detecting element, but the name implies that it is a special sort, one in which energy is converted from one form to another, and this is not true of all detecting elements. Likewise, not all transducers are detecting elements, for this category includes such devices as prime movers, converters, etc. The detecting element is thus a very important unit of a measuring or control system, and is the part with the greatest variety. Succeeding units, such as amplifier, recorder, controller, may be designed to fit one to another with more or less standard input and output conditions. But the detecting element can only deliver a signal at its own particular level, with its own particular sensitivity and discrimination*, and its own particular impedance: the following unit must therefore be designed either to accept such a variety of input conditions directly, or a converter or transmitter may be inserted to perform this initial function.

Most detecting elements sense a physical parameter—such as temperature, flow rate, optical density—and themselves work on physical principles. In the case of a simple measuring system for determining linear dimensions, say, the mechanical feelers or anvil directly sense the dimension, and can operate a dial gauge directly, often with levers or gears to amplify the movement. The feelers or anvil constitute the detecting element proper, and no energy is converted (except during the transient stage when first making contact, or when a dimension changes), both detecting element and indicator operating by change of potential energy (energy of position). On the other hand, reverting to the example of the measurement of temperature by means, say, of a thermocouple, the heat energy of the original system is directly converted to electrical energy by the action of the thermocouple: the thermocouple is thus a transducer.

As we have stated, the output from detecting elements may take several forms, but the most usual for measurement, and certainly for control, are mechanical, pneumatic, electrical and hydraulic. These fit into the most widely used systems of transmitting information and of regulating or controlling. The level of a signal transmitted from a detecting element must be high enough not to be confused with ' noise ', and pick-up of spurious signals by the transmission or amplification system must be minimized because these are handled by the succeeding parts of the system as if they were input signals. In pneumatic systems a change of 3 to 15 lbf/in^2 has been universally accepted to represent the change from zero to maximum signal. The set-up zero ensures that any leaks that might occur in the system are detectable: a drop in pressure from this cause would, in a system with absolute zero, be passed on as a reduced signal. There is not the same need in electrical systems for such an uplifted zero, though there are some proposals in the U.S.A. for such a scheme. No standard has yet been agreed for signals in electrical systems, and numerous forms exist, e.g. 1–5 mA, 4–20 mA, 0–15 mA, all d.c., 0–200 mV, 0–0·5 V a.c. and many others. There is much to be said for standardizing on the range and levels of such signals and of the associated circuit impedance. It seems to be most generally accepted that d.c. rather than a.c. should be used (mainly to avoid pick-up of spurious signals) and that control signals should be current rather than voltage to ensure that equal driving power is available at all control points. A desire to obtain standardization is evident at least in Britain* (*3*), E. Germany (*4*), U.S.S.R. (*5*), Poland (*18*) and to some extent the U.S.A. (*6, 7*).

* Terms such as ' sensitivity ', ' accuracy discrimination ', etc., are used in this article in accordance with BS 2643:1955 (*2*).

* A committee of the British Standards Institution has commenced deliberations with a view to instituting standard signals for these purposes.

When performance characteristics of a detecting element are considered, especially in relating output to input (i.e. the sensitivity), two conditions may arise which make it difficult to quote figures for the primary element alone, at least for any practical system. The first of these arises when the actual output of the detecting element is so small that a following amplifier is required before any sensible output figures are obtained. To take an example of this, a certain capacitance-type transducer, which responds to very small changes in pressure, gives a minute change of capacitance, but this cannot be used in practice without an associated amplifier, and the output must be expressed in terms of amplifier output rather than capacitance change.

The second condition arises when the primary element always has a second element associated with it, so that two conversions are involved. In this case also the output would be more sensibly given in terms of that of the second device. An example of this would be a flowmeter using an orifice plate and an associated pressure-measuring device: the orifice plate is the primary element sensing the flow rate and creating a pressure-difference related to this, whilst the manometer detects this pressure-difference and converts it into mechanical movement for indication, e.g. by altering the level of a liquid or changing the dimensions of a sealed tube.

Detecting elements *v.* measuring techniques

Before one considers possible ways of collecting data on and classifying detecting elements, another aspect might be mentioned that necessitates careful thought. This is differentiating between a detecting element and a measuring technique. It is, we believe, easier to prepare lists and descriptions of measuring techniques, since it is the overall concept of a system that first comes to mind. In fact, such books and lists already exist.

In the case of a detecting element which is also almost a complete instrument, no difficulty arises. For example, the Bourdon tube in a pressure gauge is the detecting element, but it is practically also the complete instrument, since it needs only the addition of gearing and a pointer to magnify the movement resulting from the conversion of pressure to volume change, and hence to mechanical movement. A Bourdon-tube pressure-gauge fits equally well into a list of detecting elements or a list of measuring techniques or instrument technologies.

At the other extreme we might instance an instrument for analysing the concentration of one material in another. Under measuring techniques this can be grouped with many other different instruments under the general title 'analysis', and one may instance techniques such as infra-red spectrometry, or gas chromatography and the like, and be able to describe and list complete instruments of this type. But, 'concentration' is not a physical parameter, only a relative value indicating the ratio of two quantities, so 'analysis' or 'concentration' cannot appear in a list of parameters associated with detecting elements, nor can any reference to infra-red spectrometers, gas chromatographs and the like. Detecting elements are certainly used in these, but they sense some actual property, even though they may do this in a differential way. One must look therefore for the parameter measured; in the case of the infra-red spectrometer this is thermal radiation, so that an appropriate detecting element is a thermopile, bolometer or photo-conductive cell, and these would be listed under 'radiation (heat)': in the case of vapour chromatography one of the commonest parameters measured at the output of the instrument is thermal conductivity of the separated vapour phases in the carrier gas, and such a detector would be listed under 'conduction (heat)'.

Instruments of the types just discussed also raise the question of what the primary detecting element actually is. In the spectrometer we wish to determine radiation-intensity at different wave-lengths, and to do this we must have a dispersing or filtering system to sort into separate wave-lengths so that the radiation-intensity detector is able to signal proportionally to the intensity of each. In the gas chromatograph, again, there must be separation of the input components, and this is done in the absorbing or adsorbing column so that the different constituents emerge from the column to the detector separated in time, and the detector provides sequential signals from the different constituents. Ought the dispersing or separating systems in such devices to rank as the primary detecting element? They are certainly necessary before the detecting element producing the output signal can operate, but only to isolate or divide the input into constituents or parts. They do not of themselves produce an output signal in any form, so we do not count such devices as detecting elements; even though, in a sense they 'detect' the different wave-lengths or different constituents, they do not accord with our original definition of a detecting element.

Principle of operation—VARIATION OF RESISTANCE

ELEMENT	WILL DETECT	INPUT RANGE	ACCURACY	DISCRIMINATION
Resistance thermometer—wire	Temperature	−240° to 600 or 1000°C		1×10^{-4} degC
Thermistor		−100° to +300°C	±0·1 degC	0·1 degC
Strain gauge	Strain		±0·25%	
	Weight	0 to 50 ton	±0·25%	

TABLE I Example of part of entry sheet for classification by principle of operation

It will be seen, therefore, that the task of classifying detecting elements, and subsequent use of any classified system, necessitates some care in deciding what is the true detecting element, what is the parameter really measured, and whether the element comprises more than one converting device.

Classifying systems

Three ways of classifying detecting-elements immediately present themselves. These are by (a) basic principle on which the element operates, (b) type of element, (c) parameter to be measured. These are the principal headings for the primary classification, but in each an attempt should be made to include the other headings as secondary items.

BY PRINCIPLE OF OPERATION Most often the principle of operation depends on some physical effect, such as linear dimension, change of volume, variation of resistance, generation of electromotive force, absorption of radiation, etc. The above effects can be used, for example, to detect thermal expansion, pressure, temperature, optical density, respectively. In this way an entry for a single effect might appear as in Table 1.

This method of classification is not very practical, for it does not tell us much about the capabilities of the detecting elements in range, accuracy, or discrimination. Grouping in this way fits information more aptly into chart form, where conversion from one form of energy to another can be specified in terms of the physical effect noted (*8*). Such a chart will inherently cover large-scale power-conversion devices as well as detecting elements for measurement. It will show what conversions are possible, and, if the names of the detecting elements are included, will indicate what effects have or have not been used in detecting elements, For deciding on what detecting element to use for a given measurement, it is not as useful as forms of classification given below.

BY TYPE OF ELEMENT This system lists elements by general name, as 'differential transformer'. 'photocell', 'Bourdon tube', etc. and enables one to give descriptions and the characteristics of each type. It is a good way of comparing units of the same type against one another, but does not enable one to set the merits of one type against another readily where both types may be used for measurement of the same parameter. It does not, in fact, easily show what element could be used for measurement of a given parameter: secondary entries could be made for each element to indicate which parameter it can be used to detect, but this only in a broad way. A preliminary survey made by the British Scientific Instrument Research Association was based upon this system (Table 2).

We have already noted that in some detecting elements more than one 'action' is involved. An interesting paper by Grave (*9*) proposes a schematic representation of the method of operation of measuring

TYPE OF ELEMENT	INPUT RANGE	ACCURACY	DISCRIMINATION	WILL DETECT
Differential transformer	Micro-inches to inches	±½%	0·1%	Length, displacement
Bourdon tube	0–10 lbf/in² 0–80,000 lbf/in²	±1–1½%	1%	Pressure

TABLE 2 Part of a table of detecting elements based on listing the type of element

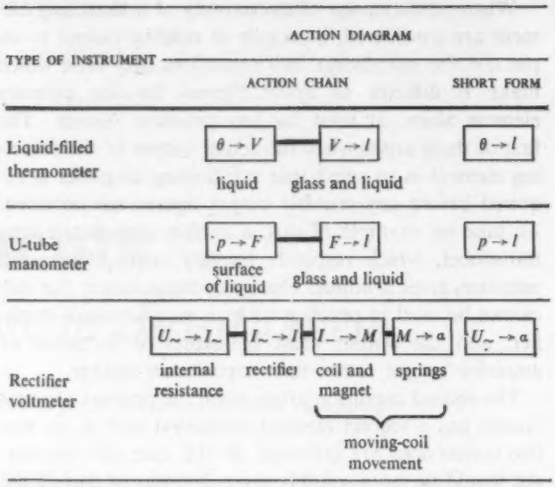

TABLE 3 Illustrating action diagrams for measuring devices (after H. Grave (*9*))

θ = temperature, α = angle of deflexion, V = volume, l = length, p = pressure, F = force, $U\sim$ = alternating potential, $I_\sim$ = alternating current, I_- = direct current, M = torque

instruments: as it is equally applicable to detecting elements, we outline the scheme here by quoting a few examples: this scheme is almost self-evident from the diagram (Table 3). The author proposes these action diagrams to supplement assembly drawings, since they reveal the mode of action without text. In the liquid thermometer the temperature to be measured (θ) affects the volume (V) of the thermometer liquid: the shape of the vessel is such that this leads to a change in length of the liquid column (l). Thus θ is represented by l and this abbreviated form is given in the last column of the diagram whilst the intermediate steps are shown in the centre of the chart. In a U-tube manometer the pressure to be measured (p) produces a force $F = pA$ on the liquid column: this force is in equilibrium with the weight of the opposing liquid column of length l. Hence p is represented by l through the intermediary of the force F. The original paper should be consulted for other devices.

We might refer to a performance coding system devised by Keller (*10*), primarily for instruments used for measurement and control, but containing a division for transducers. The system is based on the use of cards edge-punched according to a system of class marks given to the device at the time of compiling the card. The coding classes deal with: type of input; type of output; precision; stability of calibration; rate of performance; mean shelf-life; mean time of failure; mean repair-time; cost; availability; volume, From an index chart which gives these classes and the meaning of the numbers in each class, one can insert selecting needles in the appropriate holes in the cards and draw those out that comply with the number code to meet the particular specification.

BY PARAMETER TO BE MEASURED This system is certainly the most practical and probably the most logical. For

the user of a classified list, the most likely requirement is to find elements for measurement of a parameter.

In this system, detecting elements are divided into groups depending upon the parameter to be measured. Thus each parameter will have associated with it all the different types of detecting elements, and all their types of output when used for sensing the particular parameter. As an example, for measurement of pressure we could have: Bourdon tube, bellows, diaphragm, U-tube manometer, inverted bell, piezo-electric element, capacitance transducer, Pirani gauge, etc. By setting up in this way, the merits of one method of detection relative to another are made apparent, and the range of measurement that can be covered by each indicates the general field of use.

It is clear that some detecting elements will appear under more than one parameter because they may function equally well under two or more distinct sets of conditions. For finding the known applications of a given kind of detecting element, classification by type as above is more useful, but, in comparison with the advantages outlined above for classification by parameter, this is a small loss to suffer. By elaboration and use of special retrieval methods, even classification by parameter could be made to give such information, if suitable coding were introduced.

Classification by parameter has also been the classification most used so far, and we refer the reader to an early compilation of transducers for oscillography (*11*), to a descriptive and illustrated guide (*12*, *13*) to all elements required in an instrumentation system (which therefore includes detecting elements), to a book (*14*) dealing solely with transducers giving an electrical output signal, and to a tabular review (*15*) which, whilst dealing with measuring techniques, can be regarded as concerned with detecting elements for a large number of its entries: a study (*16*) has also been made of transducers used in the aircraft industry. As a variant of this theme, a chart form of presentation has been given by Geary (*17*) showing conversion from various parameters to the several electrical effects, e.g. resistance, capacitance, frequency of oscillation: thus the general effect used for each conversion, rather than the type of element, is quoted in this case. The same remarks apply to the several handbooks which deal with instrument technology, again if the treatment of detecting elements alone is extracted from them.

Sira's contribution

Believing that classification by parameter is the most generally useful system, especially to the practising instrument engineer, the British Scientific Instrument Research Association is compiling a list of detecting elements based upon what is commercially available: this will therefore be complementary to the Association's early work, which dealt with the principles of operation of the various types of element. The Association is running a Detecting Elements Bureau, which it was nominated by the Servo-mechanisms Sub-committee of the Scientific Advisory Council of the late Ministry of Supply to establish as a national centre in this respect.

The first requirement was to list the parameters that might need to be measured, and there were found to be over 200. Not all of these are of equal importance, or likely to be used, so the first part of the work has been concerned with those most widely used and for which the largest number of alternative detecting elements are available.

Although this compilation is in the first instance based upon detecting elements which are commercially available, it is more than a catalogue of manufacturers' products. The entries are designed to show the type of detecting element, the total range in the measured value over which it may be used, the form of the output signal (e.g. mechanical, electrical, pneumatic), and the accuracy and discrimination that are generally achieved. Several other items and any special features etc. are also noted. Table 4 is an example of part of a typical entry on this scheme.

To measure—PRESSURE

ELEMENT	OUTPUT	INPUT RANGE	ACCURACY	DISCRIMINATION
Bourdon tube	Mech.	0–10lbf/in² 0–80,000lbf/in²	±1–1½%	1%

TABLE 4 Example of part of entry sheet for classification by parameter

It has been noticed during the compilation that, whereas new *manufacturers* may start making a certain type of detecting element, the number of instruments appearing that work on new *principles* is limited, so the number of new entries required is not too large, and the system permits them to be added.

It has been found that the headings for the entry sheets can be used for any type of detecting element so far studied, so they appear to have been well chosen.

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A model-borne incidence-measuring device is the sensor for a digital servo-mechanism that automatically fixes the model's attitude, regardless of other conditions in the wind tunnel

Digital inclinometer for automatic incidence setting

by **G. P. TONKIN** B.Sc., *Bristol Aircraft Ltd*

MODEL-ATTITUDE MEASUREMENT WAS RECOGNISED EARLY in a Bristol wind-tunnel design as a weak link in the chain of data, and particularly so in the incidence case. It is, perhaps, not so difficult to instrument the yawing turn-table of a subsonic tunnel, but in the pitch plane reliance had to be placed formerly on the alternatives of instrumented tail-wire winch or sighting (telescope) inclinometer, suitably corrected for angle of yaw. Furthermore, while the former may be criticized because of triangular effects and wire stretch, the latter is not only of limited accuracy (0·1°) but does not lend itself to digital output.

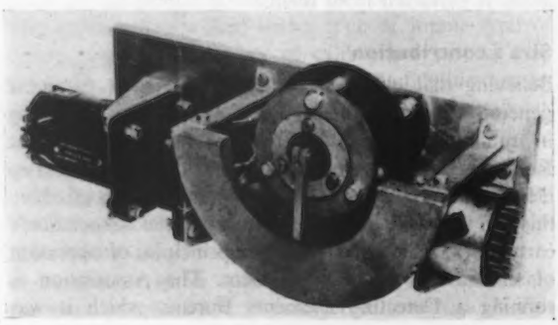
Accordingly, in 1956 a servo-inclinometer for mounting within the model was postulated, and the movement was manufactured during the following year. Its ultimate basis was the Elliott 'a.c. pick-off' with a pendulum attached. This transducer produces 1·5mV per hundredth degree with 10V energizing. It was mounted in the centre of a gear, driven by a servo-motor, and geared also to a multi-turn digitizer (four decade) with such a ratio that one digit corresponded to a hundredth-degree rotation. It was found possible with this mechanical arrangement to read incidence to a fiftieth-degree with suitable servo-amplifier and digital decoder. It was then necessary, for lack of available effort and through lapsing immediate requirement, to leave the matter at this stage for a considerable period.

In 1958 a series of tunnel tests arose in which, to allow for interaction and computation, it was desirable that precisely the same set of incidence values should be used in each of a set of runs with other parameters varying. This could not be accomplished without lengthy calculations at each setting combination, using normal measurement methods for incidence, and it was decided instead to use the servo-inclinometer as a unit of a larger digital servo-loop. In this, particular digital combinations would be called in turn, and the incidence actuation operated until the servo-inclinometer read likewise. The system about to be described, giving automatic control of attitude by digital inclinometer, was the result.

The inclinometer

The movement, already briefly mentioned, is shown in Fig. 1. No attempt has been made to keep its size down in view of its experimental nature, and the result is a simple flat-plate assembly. Some trouble was taken with the pendulum 'bob' shape, particularly as it was expected that any viscous damping required would be

Fig. 1 Inclinometer movement



applied here: a trough for the damping fluid surrounds it as it turns relatively to the transducer case. Limit switches prevent overrun by the motor.

Since each digit corresponds to a hundredth-degree, the capacity of the system with a 1-in-10,000 digitizer is 100° or ±50°. The digital coding makes no provision for direct reading about a zero, but corrections are applied in subsequent computation for whatever point is defined as zero by a preset switch on the control panel.

The digitizer is of the standard R.A.E./Petherick type (2) (manufactured by Willcocks (Clevedon) Ltd) in common with many other such transducers in the tunnel's data-logging system. The rotary Elliott transducer is regarded as expendable, only because it is desired to make use of the extremely low friction which, at least in early life, it possesses.

The system

Fig. 2 shows the various units in their geographical locations, and the original servo-inclinometer sub-system can be traced out in the upper part of the figure. The Elliott rotary inductive transducer in the model is energized with 10V 2000 c/s a.c. from the source unit, and its output feeds the servo-amplifier which in turn drives the servo-motor in the model. When the transducer output is zero the motor is quiescent, and the attitude is fed from the digitizer to the *data read-out equipment* (2).

Mounted at and in the control desk of the tunnel is the sub-system for incidence demand and reading. On the *multiple-encoder* the tunnel operator can set up thirty different four-decimal-digit numbers, corresponding to the sequence of incidences which he will desire to be repeated many times during the test, while these are selected in turn by a combination of two switches on the *control unit*. Each appears as a number on the in-line indicator provided for monitoring, at the same time passing on as an incidence 'demand'.

The output of the model digitizer, while being connected to the data read-out system as mentioned above, also passes through its *isolator* (a current-limiting device) to the control unit, where it is decoded to decimal, displayed as a number on a second in-line indicator, and passes on as a 'present-state' indication.

The *decimal subtractor* acts as the digital servo sensing device or comparator, and is fed with both 'demand' and 'present-state' information. It compares these, and from the result calls for forward or reverse motion of the incidence motor. When, as the digitizer changes, they are within a certain specified number of digits of parity, 'inching' is called in place of fast motion, until coincidence is reached: then motion is stopped and the control unit indications should be alike.

Having so dealt with one selected combination from the multiple encoder and obtained tunnel readings, the operator then proceeds to the next. The control unit provides him with various indications and local switching to facilitate operations.

Effectively a third sub-system is the means of tail winch-motor actuation. Originally a single-phase single-speed machine, manually operated by relays and a system of key switches, the motor was rewound for three-phase working so that a d.c. energizing inching system could be used. This necessitated introduction of the *motor contactor panel*. However, all calls for operation still pass through the basic tuned system, and it

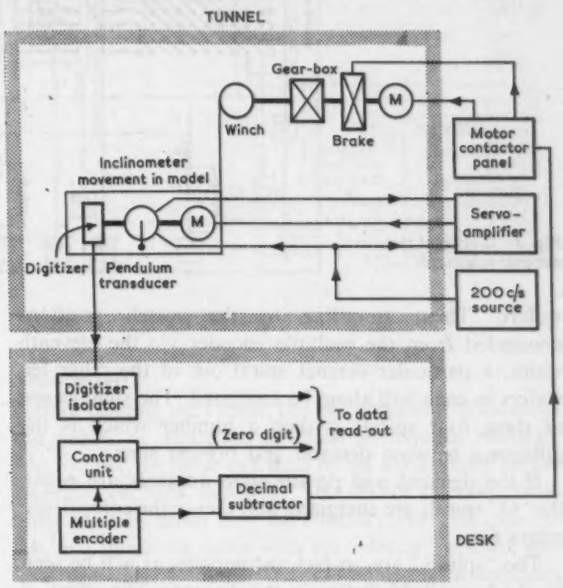


Fig. 2 Block diagram of the digital inclinometer system

is so arranged that manual calls override demands from the automatic circuits.

Conventional electronics is used in the carrier amplifier/discriminator/power amplifier. There are two stages of amplification from the Elliott transducer, which is fed from the 2000c/s source.

Decimal subtractor

The circuit of this unit appears as Fig. 3. As the digital comparator, it is the kernel of the system (3). It operates in decimal code, and the main components used are multiple-wafer Ledex solenoids. There are four such switches, corresponding respectively to *most, more, less* and *least* significant characters of the numbers, and each has eleven effective wafers.

Incoming preset decimal combinations, selected from a multiple encoder *via* Skt. 1-4 and demanding particular incidence-settings, energize the appropriate contact of each eleventh wafer. The wiper of the latter is taken to ground *via* the Ledex drop-out relays *D*, so that the solenoids *L*, using their own interrupter contacts *via D* contacts, motor until the energized position is reached. Thus the demand is set up as particular positions of the four actuated switches.

The digitizer output, decoded to four-digit decimal in the control unit, is presented *via* Skt. 5-8 as energization to the wipers of the 'spirally' connected bank of ten

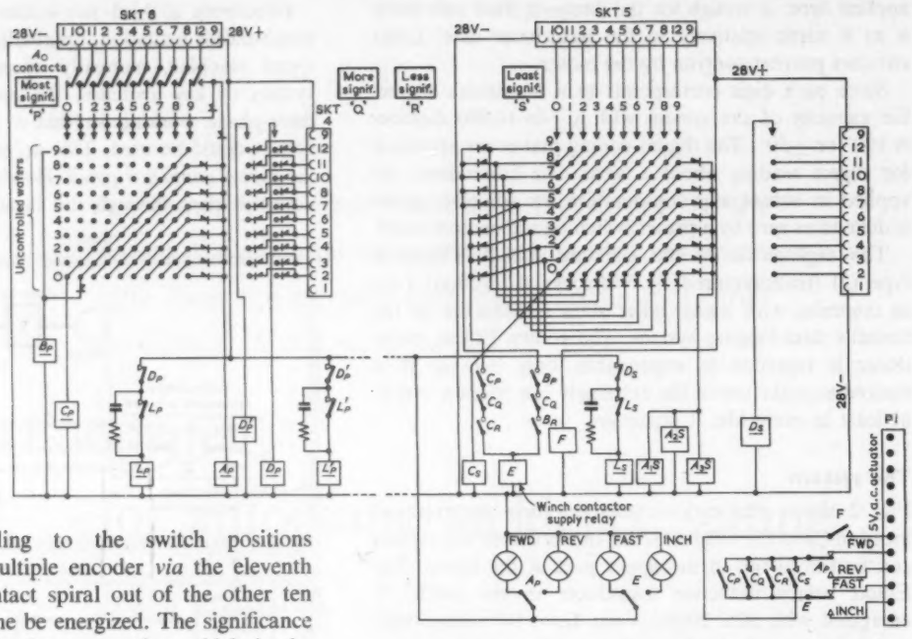


Fig. 3 Circuit of the decimal subtractor

wafers. Thus, according to the switch positions demanded from the multiple encoder *via* the eleventh wafer, a particular contact spiral out of the other ten wafers in each will alone be energized. The significance of these four spirals is then a number which is the difference between demand and present state.

If the demand and present-state numbers are equal, the 'O' spirals are energized, and thence the coincidence relays *C*.

The 'spirals' are, in fact, incomplete, as will be seen by the 'unrolled' wafers in the diagram. The effect of this is to divide the field of contacts into two halves. The partial spirals in one side of these contacts are energized for numbers above the demand, and in the other side for lesser numbers. Only the 'O' spiral is complete, and has a special function as mentioned above.

When the demand is the lesser, rectifier-isolated paths are provided to the 'carry' relays *A*, which temporarily advance the next significant 'present-state' input by one digit. (This does not, of course, apply to the least significant.) This operation is none other than the ordinary 'carry' in a decimal subtraction sum, and has, as its result, the operation of the most significant *Ap* relay whenever present state exceeds demand. There is no further 'carry' function for this relay, but it is used to indicate the requirements for reverse motion *via* the contact associated with the output connector Pl. 1.

Any absence of coincidence initiates motion in the appropriate direction towards coincidence, and as this occurs, so a stage of nearness is reached in which a slower approach is desirable for better response. To cater for this, another set of rectifiers can be attached to the wafers of any one of the digits. In practice it has been found most convenient to use the least significant decade for this purpose, and the diagram shows the parallel connexions of lines, signifying differences of five or less, taken to the 'slowing' relay *E*, the contact of which passes this information to the motor control gear, again *via* Pl. 1.

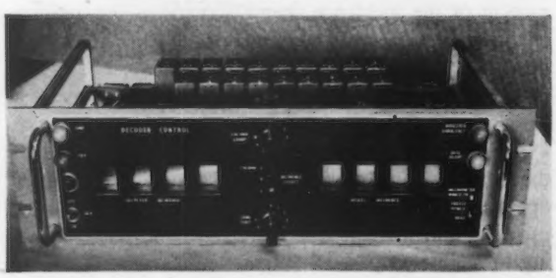
Lamps indicate which of the four commands are being issued from the unit at any one time, *forward*, *reverse*, *fast* and *inch*. These are not intended for operational purposes, but as a guide in setting up and servicing.

Control unit

This unit (Fig. 4) is the only one mounted on the desk face for the operator's use, and its diagram is given in Fig. 5. The contents fall into five sections: digitizer decoding/presentation, selected-incidence-demand presentation, demand selection, zero-digit generation, and supervision.

The digitizer leads have passed through the isolator by the time they enter this unit at Skt. 1. Four sets of WXYZ relays are then used for decoding, with three intermediate odd/even relays *S*. It will be seen that the two halves of the resulting decoding 'trees' are unsymmetrical (leaving aside the *S* contact interventions in all but the most significant). The contact requirements are thus shared more uniformly among the relays. The odd/even chains for complementing or otherwise in the cyclic decoding operation have additional *S* contacts from the next most significant digit in the less- and more-

Fig. 4 Control unit



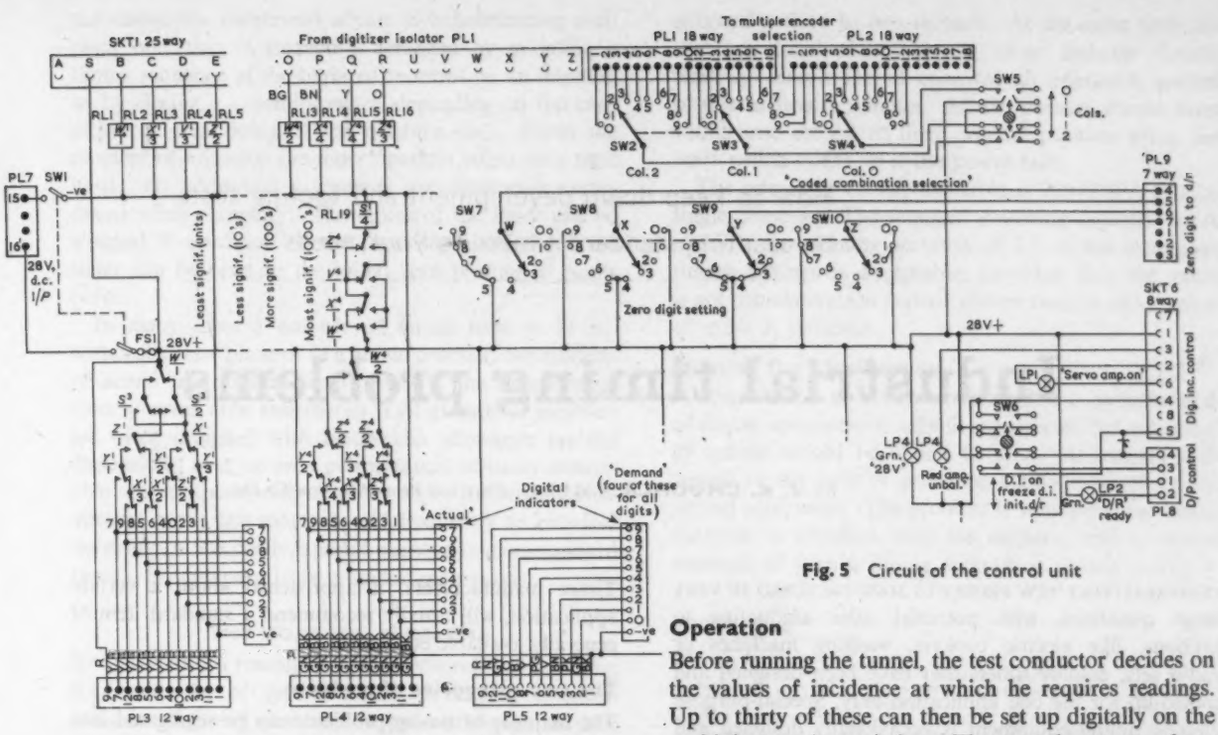


Fig. 5 Circuit of the control unit

significant cases, while the complementing operation actually takes place, as indicated in brackets above, beneath the *W* contact of all 'trees' except the most significant. The tree inputs feed Hilger in-line indicators and the subtractor *via* Pl. 3-6.

The presentation of incidence-demand on another four-digit set of in-line indicators *via* Skt. 2-5 is a spur only to the main demand circuit from multiple encoder to subtractor. Selection of the decimal combination from the multiple encoder is by Sw 5 and Sw 2-4, *via* plugs 1 and 2. The former switch is a key type and determines column, while the latter is a rotary ten-position type for rows.

A further ten-position switch, Sw 7-10, is a standard Petherick-code digit-generator to feed into the sequence a single digit indicating the number of thousands at which the inclinometer zero has been set.

Winch motor control

It is at this point that the digital inclinometer system connects to existing tunnel control and instrumentation. The three-phase supply to the motor passes through suitably interlocked forward/reverse contactors *C* and *D*; a three-phase Variac transformer is used to preset the supply to suit the test on hand. 'Inching' is by substitution, *via* other contactors, of a commutated d.c. for the three-phase a.c. supply. A 50V.d.c. supply *via* contactor *E* supplies the commutating motor. To prevent overrun, and facilitate the change-over from 'fast' to 'inch', an electromagnetic brake is applied momentarily at the transition, while 'fast' and 'inch' relays are operating together.

Operation

Before running the tunnel, the test conductor decides on the values of incidence at which he requires readings. Up to thirty of these can then be set up digitally on the multiple encoder switches. The tunnel operator from then onwards needs only the control panel. He calls for his first incidence value with the selector switches, and it is presented to him on the left-hand digital indicator as a check. Raising the right-hand control key to the up position, he energizes the inclinometer model servomechanism and at the same time the winch motor system. At quasi-stabilization of the former, the actual incidence is readable from the right-hand digital indicator, changing as the winch motor drives it towards parity with the desired incidence in response to the calls of the digital subtractor/comparator. At five characters from equality inching is called, and final identity is reached. The operator then returns the right-hand key to centre, freezing the winch pending stabilization of measuring equipment, and finally depresses it, when ready, to actuate the digital read-out system.

Pointer to further applications

The system is an example of the integration of the analogue with the digital in a control system. Based on a relatively slow digital comparator as detector of deviation from requirement, it may point the way to further applications as data become more and more available in suitable form.

Acknowledgement

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How to keep down development and tooling costs by adapting standard timers to your needs

Industrial timing problems

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COMPARATIVELY FEW PRODUCTS MANUFACTURED IN VERY large quantities, with potential sales amounting to millions, like electric cookers, washing machines or radio sets, employ timers that have been designed and tooled-up for the one application only. Special-purpose electric timing equipment is occasionally designed and manufactured for unusual scientific or research apparatus, but timing devices already on the market, running into hundreds of types, cover the vast majority of industrial and consumer applications. Prices vary with quantity, naturally, but rarely are the development and tooling costs of a completely new timing device justified unless the annual demand exceeds tens of thousands a year. Development and tooling costs can very frequently be reduced if a standard device is suitably modified to meet a special application.

Selection and adaptation

The main problem in the design stage is usually to select or adapt one of several alternative timers, to meet a set of conditions determined by product or plant requirements.

A manufacturer planning the marketing of a new product is usually greatly concerned to keep the details of the project from competitors, and the disclosure of some details to a maker of timing equipment might appear indiscreet. This need not be so if the data supplied are concerned with timer specification only in terms of operating voltage, timing cycle, means of external control, switching capacity, overall dimensions, etc. The usual function of timers is closing and/or opening electrical circuits at required intervals, and practically identical times can be used for spot welding, electrocution of poultry, or dispensing of abrasive compound in a polishing machine. The same contacts on a timer can be used to switch a contactor coil, energize a fractional-horsepower motor, operate a relay, connect a transformer, or switch a solenoid-operated valve. Timer manufacturers, if approached about a certain application, will usually recommend a standard item of generally available equipment.

The two categories of problem

The majority of timing problems can be segregated into two categories:

1 Control of equipment according to a rigid timing schedule, with the timing device determining—on time alone—whether and how the equipment should operate. A timing device with an independent time basis lends itself most readily to master control of appliances.

2 Performance of a certain function involving timing, but with the timing action depending on the condition or speed of operation of the plant in which the timing equipment is used. Timing in this instance takes place only if the equipment is ready for a particular operation.

The typical example of **1**, master control based on time alone, is the flashing of a neon sign. If the neon-sign installation is in working condition it should operate on a time basis only.

An example of **2** is automatic sampling with timing equipment. If plant is not working, or operating faster or slower than usual, simply sampling at regular intervals would produce misleading results. In problems of this nature it is occasionally possible completely to eliminate the independent timing element, and, for example, couple the timing mechanism directly through a suitable reduction gear to the main motor. Assume, for instance, that every thousandth item produced on a machine will be taken for sample checking by energizing a solenoid to operate a trap-door that diverts the item for sampling. When the machine is working at uniform speed, opening of the trap-door on a simple time basis might produce quite satisfactory results. However, when the motor driving the machine is also driving the timing mechanism itself, automatic sampling will be quite accurate even when the speed of the machine alters. In fact, a timing problem has been reduced here to a counting problem.

The vast majority of timing problems involve both of

the categories mentioned above. Synchronization with plant operation is frequently arranged by initiating a timing sequence at the required moment by an impulse, or by closing a control contact, depending on the condition or positioning of the machine only. From the moment of initiation the timer operates solely on a time basis, but additional safeguards are commonly introduced when necessary. The motor of the timer can be stopped if operation of the plant lags behind, or the timer can be reset to the initial zero position if faults occur.

In many cases a number of timers have to be incorporated in a plant or in a single product, but analysis of actual timer requirements early in the design stage usually saves time and money. Unfortunately, products are often designed with inadequate allowance for the dimensions, cost, or even performance, of easily obtainable and inexpensive timers. The result is hurried development at the last moment, and frequently an eventual necessity to use costly, special-purpose or non-standard timers, for comparatively unimportant reasons.

THE CONTROL PROBLEM

By considering a reasonably complex specification calling for a number of typical timing devices, a common solution of timing problems in product design may be illustrated.

A complex specification

Two electrical circuits should close alternately for a period of twenty minutes at thirty-minute intervals, the cycle repeating every hour. At the same time another electrical circuit should close and open alternately at intervals with a period of ten minutes. If power fails the timer should stop (but not reset itself), and resume the time cycle at the same point on restoration of supply.

Means should be provided to open, for an adjustable period of five to 25 minutes, both electrical circuits, closing alternately at thirty-minute intervals. If power fails, the time during which power is off should not influence the interval for which the circuits were intended to be open while the plant is working.

If an external push-button is pressed during the sixty-minute overall timing cycle, the following timing sequence should take place.

At the beginning of the next complete timing cycle three additional electrical circuits should be closed at five-second intervals. The first two circuits should remain closed for an adjustable period of thirty to fifty seconds. The third circuit should remain closed for two seconds only. If power fails, all three circuits should be reset to their original position within one second.

The following timing cycle should take place if an external switch closes while the second circuit, mentioned at the beginning of the specification, is in the closed position. One electrical circuit should close and another electrical circuit should open after an adjustable delay of a third to two seconds. At the same time the third electrical circuit should close and the fourth electrical circuit should open for an adjustable period of five to twenty minutes. All the circuits should reset within one second to their original position when the limit switch opens or if the power fails.

The operating voltage available is 200/250V, 50 c/s, single-phase a.c. The required switching capacity is 3A at 250V a.c. Timing accuracy of 1% of the maximum timing settings is acceptable, provided that the error is not cumulative. On periods shorter than 5s an accuracy of ±5% is sufficient.

Meeting the specification

A specification as above would enable a manufacturer of timing equipment to submit suggestions, but a number of queries would be bound to arise, particularly with regard to the duty or switching action required of the timing equipment. The problem is simplified if a timing diagram is supplied with the enquiry, and a typical example of such a timing diagram is shown in Fig. 1.

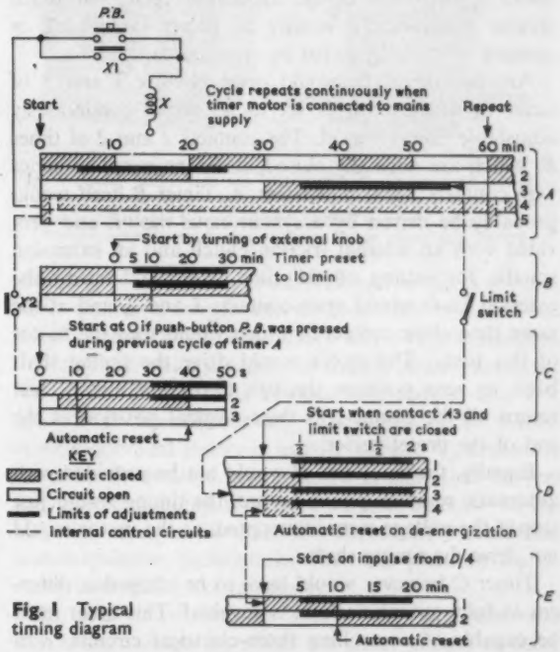


Fig. 1 Typical timing diagram

The continuous line shows the electrical circuits necessary for performance of the switching action as per specification, and the circuits shown in interrupted line would be added by the manufacturer of timing equipment for internal control and interlocking.

The complete unit would have to consist of a number of timers, which are marked as *A*, *B*, *C*, *D* and *E* on the timing diagram. The timer *A* has to repeat its cycle every sixty minutes without automatic reset. A large variety of synchronous motor-driven cam-operated timers would actually be available for such application, and in this instance continuously adjustable cams would be an advantage to provide adjustable intervals of five to 25 minutes. This timer has two electrical circuits

added. Circuit 4 is closed practically throughout the cycle, so that if an external push-button is pressed an external relay can energize and back itself, through circuit 4, to the mains supply. One of the relay contacts, connected in series with circuit 5 (which is closed for a short period at the beginning of the cycle) would provide means of energization of the timer *C* at the beginning of the cycle if the external push-button were pressed at any time during the previous cycle. The timing diagram shows instantly some of the limitations of a particular scheme. In this case, if the external push-button is pressed while circuit 4 is open, the relay will not latch-in, and another part of the sequence will not take place. Every timer has a minimum timing interval, and in the case of cam-operated timers this interval in one electrical circuit depends on the time taken for the roller of a microswitch to go into and climb out of a cut in a cam, or it might depend on practical limits of adjustment between the dropping-in of two steel riders. The usual minimum timing interval is in the neighbourhood of a sixtieth of the maximum cycle, but much shorter intervals can usually be preset for closing or opening contacts operated by separate cams.

Another timer, *B*, would open circuits 2 and 3 of timer *A* whenever it is set to a certain continuously adjustable timing period. The contacts *1* and *2* of timer *B*, which are normally closed, could be wired in series with contacts *2* and *3* of timer *A*. Timer *B* itself would probably be driven by a synchronous motor, and provided with an internal friction clutch and an extension spindle for setting of the time interval. Turning the external knob would open contacts *1* and *2*, and at the same time close contact *3*, which would feed the motor of this timer. The motor would drive the timing shaft back to zero position through a friction clutch, and return all the contacts to their original position at the end of the preset period.

Equally, timers *A* and *B* would not be provided with automatic reset on power failure, the timing would just stop if the voltage were interrupted, as the motor would not drive the timing shaft.

Timer *C* however would have to be altogether different as fully automatic reset is required. This timer must be capable of controlling three electrical circuits, with the time-setting in two of them continuously adjustable. Timers of this type are extremely versatile, and a sequence as illustrated might be used, for example, to start at short intervals three large electric motors, while simultaneous switching-on of all three motors would put an extremely heavy starting load on the mains. Circuit 1 of timer *C* would maintain the voltage supply to the motor and the electromagnetic clutch of timer *C*. Some timers have the clutch built into the motor, which simplifies the circuitry but is not always acceptable if very fast automatic reset is an advantage. Commonly, a resetting spring or a spring-loaded cam is used to reset the timing device, and the resetting time is then under a second.

Closing an external limit switch in series with circuit 3 of timer *A* could energize timers *D* and *E* when circuit 3 is closed. The timing sequences of timers *D* and *E* should take place simultaneously, but the use of one timing instrument only would be inadvisable because of the wide discrepancy in the intervals for which circuits 1 and 2 of timer *D*, and circuits 1 and 2 of timer *E*, should operate. Timer *E*, with the range of five to twenty minutes, would probably be completely inaccurate, or even incapable of establishing intervals of a third of a second. Besides, multiple-circuit multiple-interval timers, with fully automatic reset and capable of extreme accuracy, are very expensive, and the more common single-interval multiple-circuit timers will be sufficient for this application.

Timers *A* and *C* were capable of establishing several intervals and operating simultaneously a number of electrical circuits. Cam-operated timers, with or without individual time dials and fully automatic reset, usually provide an inexpensive solution to this type of problem. However, for a very wide variety of applications, timers controlling one adjustable period only are quite sufficient. Timers of this type usually have an external dial with a knob or pointer for adjustment of the time setting. Some single-interval timers can close or open one circuit only for or at the end of the timing period, but quite a number of single-interval timers can close several contacts at the beginning and/or at the end of the timing period. In single-interval timers no sequence takes place while the timing is in progress.

An electronic or capacitance-discharge timer would in all probability be most suitable for use as timer *D*. The energization of an electromagnetic clutch, and starting of a miniature motor, can easily take a third of a second, which amounts to a considerable error in a period of a half or two seconds. This timing error is

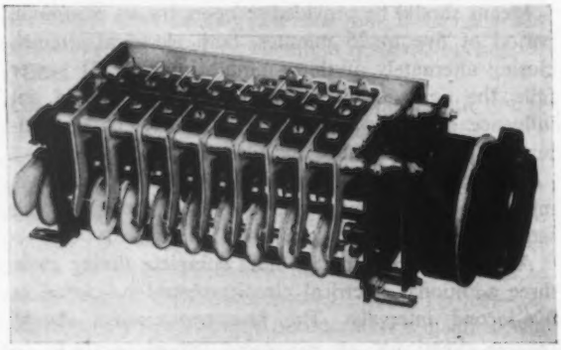


Fig. 2 Multiple-circuit, multiple-interval, cam-operated timer. Automatic resetting to zero position in 1s.

usually constant and independent of the time range, so for longer periods of, say, five to twenty minutes, the inherent error can actually be a very small percentage of the total period. Electronic timers are suitable for very short intervals.

Timer *D* has circuit 3 for internal control, to keep the timer energized after expiration of the period, but before

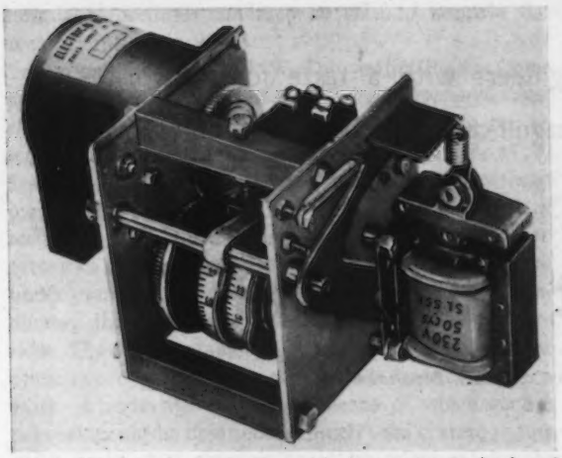


Fig. 3 Miniature automatic timer with electromagnetic clutch and synchronous motor drive. Drum dials allow independent and continuous setting of individual timing circuits

the external limit switch opens. Circuit 1 of timer *D* is open in a de-energized position, and continues to be open through the period. Circuit 2 of timer *D* operates in reverse. It is desirable, and frequently essential, to state the condition of contacts before and after energization of the timer, and after the end of the timing or in the timed-out position. Timer *D* also has another contact, *4*, which is used to energize timer *E*. Timer *E* could also be energized directly by the limit switch, as the position of contacts *1* and *2* on timer *E* after the end of the timing (i.e. in the timed-out position) is the same as the position of contacts before energization. However, if the limit switch directly energizes timer *E*, a holding contact would have to be provided to prevent resetting of the timer while the limit switch and circuit *A*3 are closed, when the timing period of *E* is ended. Resetting in such conditions would result in the repeating of the timing action of *E*, but as no definite time interval would be allowed for resetting, the repeated period would be not only uncalled for, but also inaccurate. If timer *E* is energized by an impulse from contact *4* of *D*, it can reset automatically at the end of the timing period, while *D* can reset only when the external limit switch opens and open-circuits contact *3* of timer *D*.

Each of the timers could, of course, be used separately to solve some simpler timing problems. In each instance, a simple timing diagram facilitates specification and eliminates the errors which are so easily caused by ambiguous or insufficient description of switching action. It is essential to state how the timing operation is to be initiated. An entirely different type of instrument might have to be used if the action were initiated by a fraction-of-a-second impulse rather than by permanent switching of mains voltage supply, or closing of an external limit switch for a long period.

General considerations

The means for automatic or hand resetting also considerably alter the choice of instrument. The limits of adjustment and timing accuracy can considerably affect the price of the equipment.

With the general tendency towards miniaturization, overall dimensions play an increasingly important part. Some types of miniature timer are now firmly established on the market, saving space and weight, and giving better performance. However, it has to be remembered that if large switching capacity or extreme time-setting accuracy are of primary importance, miniaturized equipment might not provide the solution. Switching capacities of 1–10A at 230V a.c. are quite usual, and it is advisable to specify the maximum inrush current and the number of operations expected from a switch on a timer.

Additional pitfalls have to be avoided in the choice of operating voltage. Inexpensive timers can usually be

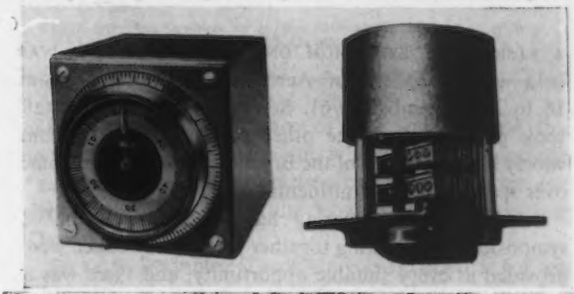


Fig. 4 (left) Single-interval automatic timer in wall-mounting enclosure. Contacts can be operated at beginning and end of continuously adjustable timing period. (right) Hand-set, single-interval timer, opening or closing contacts for an adjustable period

obtained to time-out short intervals on low direct voltage, while timing of longer intervals on 110V or 230V d.c. usually means much more bulky and costly equipment.

Mains a.c. voltage supply is usually most convenient for operation of timing devices with ranges of a few seconds to several minutes. The accuracy of mains-voltage-operated timers is usually affected by alteration in mains frequency, as miniature synchronous motors are most commonly used in these instruments. In the majority of cases the error is comparatively small and non-cumulative, particularly when the plant or equipment is working continuously.

It is essential also to specify the minimum and maximum voltage on which the timer should operate. If the product or plant incorporates components which for short periods of time take very heavy inrushes of current, the operating voltage of the timing equipment might drop well below the specified 240V a.c. De-energization of the electromagnetic clutch in a timer when the voltage drops for a fraction of a second, e.g. to 180V, might cause resetting of the whole timer.

Most timers are available for wall or panel mounting. When the quantities involved are comparatively small, it is usually a good policy to purchase timers in an enclosure, even when they are intended for housing with other instruments. An enclosure reduces considerably the chances of damage in transit, in stores, and during general handling.

To control engineers with a taste for network theory, this magnificently organized symposium was a feast

Network theory at Cranfield

by **J. W. HEAD** *B.B.C. Research Department*

A RESIDENTIAL SYMPOSIUM ON NETWORK THEORY WAS held at the College of Aeronautics, Cranfield, from 18 to 22 September, 1961. Several of the College staff took part; most of the other participants were from widely scattered parts of the British Isles. A few had come over specially from Continental countries.

Seldom can a gathering have been more truly a symposium (a 'drinking together'), for tea or coffee were provided at every suitable opportunity, and there was a special bar. The proceedings culminated in a dinner on 21 September, at which the principal items on the menu were named after some of the lecturers. Mr S. R. Deards deserves hearty congratulation for his masterly organization.

Matrices

The first paper, by Dr P. R. Bryant (G.E.C., Wembley), was entitled *Compound matrices in network theory*. If we start with a square matrix of order n (such as would arise from the coefficients of n linear simultaneous equations) we can make another square matrix (whose order is the binomial coefficient $\binom{n}{r}$) by taking all possible minors of order r and arranging them in an orderly manner. This matrix is the 'rth compound matrix' of the original matrix. Such matrices have remarkable factorization and partitioning properties, and are very relevant to the behaviour of an 'n-port' where non-zero voltages are only applied at k points. Compound matrices are closely related to the use of star-mesh transformations to eliminate unused nodes.

Next came Professor V. Belevitch (Director, Comité d'Étude et d'Exploitation des Calculateurs Électroniques, Brussels), *On network analysis by polynomial matrices*. The equations of a network can be written in the general form $MX = 0$, where M is a matrix all of whose elements are polynomials in p or $\mathrm{d}/\mathrm{d}t$, and X is a column matrix of voltages and currents. Usually M does not contain any factor on the left (other than the inevitable arbitrary factor whose elements are polynomials in p but whose determinant is a constant). An elimination process equivalent to the standard reduction of the matrix M to its Hermite normal form reduces $MX = 0$ to the form $AV = BI$ (which is more general than $V = ZI$ or $I = YV$) where V and I are vectors of voltages and currents respectively and A and B are polynomial matrices having in general no common left factor. The characteristic equation of the closed network is (determinant of M) $= 0$, and the degree in p of this equation can be determined algebraically for passive reciprocal networks with general constraints; results agree with those obtained by Bryant from topological considerations.

Calculation

From n-ports and general matrices Mr J. W. Head (B.B.C. Research Department) brought the symposium back to fundamentals with a paper entitled *Metrical mathematics and operational calculus*. For calculation, it is convenient to manipulate numbers associated with physical quantities as if they were exact, but really they are only known within limits or tolerances, the premature closure of which may lead to ambiguities and inconsistencies. The equation $V = ZI$ (for a one-port) should be regarded as operational (the impedance Z being a function of p or $\mathrm{d}/\mathrm{d}t$) and algebraic manipulations of Z are freely permissible provided that the inverse operator p^{-1} is defined as complete integration from $-\infty$ (not zero) up to the present time. If Z is expressed in partial fractions, V is obtained explicitly when Z and I are known by summing a number of terms of the form

$$v_r = \int_{-\infty}^{t} \exp\left[-\alpha_r(t-\tau)\right] I(\tau)\mathrm{d}\tau \qquad (1)$$

No transform of I need therefore be known; the integration of equation 1 can be performed explicitly in many cases, and by standard techniques of numerical integration in others. The exponential factor in equation 1 decreases (for a passive network) as τ recedes into the past. The quantities α_r are obtained by equating the polynomial denominator of Z to zero. Mathematicians ought to be grateful to control engineers for providing the root-locus method of solving equations; this enables them to locate real or complex roots roughly but quickly.

Iterative procedures can then be used to improve the accuracy if necessary.

Next came Drs Ir. A. J. W. Duijvestijn (Philips Computing Centre, Eindhoven) with *Squared rectangles and electronic computation.* A rectangle 33in × 32in can be regarded as made up of nine squares of sides 18, 15, 7, 8, 14, 4, 10, 1 and 9 inches, fitted together without overlapping. The general study of such dissections of rectangles (with the help of a computer) is related to networks (with equal resistances between each pair of nodes connected) by regarding the rectangle as a conducting sheet with electrodes applied to two opposite sides. The same rectangle, with electrodes applied to the other two opposite sides, corresponds to the dual network. A code was defined by means of which such a network could be described uniquely; the corresponding code of the dual network could be calculated by the machine. Knowing these codes for all n-node networks (having at least three wires at every node and at least three nodes where two portions of the network, each consisting of at least two wires, are connected) the computer can be used to determine the corresponding codes for similar $(n + 1)$-node networks, and whether any two such networks are topologically identical or not.

Synthesis

At this point we passed from analysis of passive networks to synthesis, begun with a paper by Dr K. M. Adams (Philips Research Laboratories, Eindhoven) entitled *A review of the synthesis of linear three-terminal networks composed of two kinds of elements.* A set of necessary and sufficient conditions for synthesis is required, when functions that specify the behaviour measured at the terminals are given. No complete set of such conditions yet exists, though partial solutions (some based on energy considerations) are known. The most important methods of synthesis available are (a) series-parallel realization, in which poles of the transfer function are systematically removed, (b) iterative introduction of internal nodes (a kind of inverse process to node elimination by star-mesh transformation), (c) nodal impedance inversion, in which the impedance matrix is bordered and inverted to obtain a directly realizable admittance matrix.

Dr A. Talbot (Imperial College) followed with *Generalized Brune synthesis.* Given the impedance Z_1 looking into the network, a reactance network X with chain matrix

$$\frac{1}{G}\begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

is sought, so that the required network shall consist of X terminated in an impedance Z_2 which is simpler than Z_1. If E_1 is the even-part numerator of Z_1, then E_1 must contain G as a squared factor. If this restriction on Z_1 is satisfied, A, B, C, D and Z_2 can be determined (a neat way of carrying out this determination by means of continued fractions was included). Darlington's method is a special case of this. Even if E_1 is not a perfect square, by appropriate arrangement of its zeros E_1 can be expressed as the difference of two squares, and this indicates that the synthesis is possible without the 'augmentation' procedure (multiplying numerator and denominator of Z_1 by the same factor) required in Darlington's process.

THESE WERE THE PAPERS

LINEAR PASSIVE NETWORK THEORY

1. *Compound Matrices in Network Theory*, by P. R. Bryant
2. *On Network Analysis by Polymonial Matrices*, by V. Belevitch
3. *Metrical Mathematics and Operational Calculus*, by J. W. Head
4. *Squared Rectangles and Electronic Computation*, by A. J. W. Duijvestijn
5. *A Review of the Synthesis of Linear Three-Terminal Networks Composed of Two Kinds of Elements*, by K. M. Adams
6. *Generalized Brune Synthesis*, by A. Talbot
7. *A New Alternative to Bott and Duffin's Method of Two-Terminal Network Synthesis*, by G. S. Brayshaw
8. *Synthesis of Linear N-Terminal Networks*, by O. P. D. Cutteridge

LINEAR ACTIVE NETWORK THEORY

9. *Flow-Graph and Signal Flow-Graph Analysis of Linear Systems*, by R. F. Hoskins
10. *Network Synthesis in the Non-Reciprocal Domain*, by A. W. Keen
11. *A Contribution to Active* RC *Network Synthesis*, by W. Saraga

NON-LINEAR NETWORK THEORY

12. *Non-Linear Circuit Theory by the Methods of Classical Dynamics*, by C. Cherry
13. *Search for a Complete Set of Basic Elements for the Synthesis of Non-Linear Electrical Systems*, by S. Duinker

Dr G. S. Brayshaw (Leeds University) discussed *A new alternative to Bott and Duffin's method of two-terminal network synthesis*; he had done most of this work at about the same time as Bott and Duffin, but had never published it. If $Z(\lambda)$ is a positive real function, it or its reciprocal can be expressed by the formula

$$Z(\lambda) = \frac{(A_3\lambda^3 + A_1\lambda)\,Z_1(\lambda) + A_4\lambda^4 + A_2\lambda^2 + A_0}{B_2\lambda^2 Z_1(\lambda) + B_3\lambda^3 + B_1\lambda} \qquad (2)$$

where the quantities A, B are non-negative constants, and $Z_1(\lambda)$ is a positive real function whose maximum degree in λ is less than that of $Z(\lambda)$. If and only if A_2B_2 exceeds $|A_1B_3 - A_3B_1|$, $Z(\lambda)$ can be realized in terms of positive circuit elements (excluding mutual inductance coupling) and the impedance $Z_1(\lambda)$; these elements are determined by the quantities A, B of equation 2 and certain auxiliary derived quantities. The process may have to be repeated, and it does not follow that it can be applied to $Z_1(\lambda)$ because it has been successfully applied to $Z(\lambda)$. If $Z(\lambda)$ is to be completely realizable, only the minimum of zero-frequency and infinite-frequency residue should be abstracted at each stage. Conditions for achieving this were considered; they are also relevant to the design of certain types of filter.

Dr O. P. D. Cutteridge (University of Leicester) discussed *Synthesis of linear* n*-terminal networks.* The process considered, and illustrated by two numerical examples, is a 'bordering' process inverse to the elimination of unwanted nodes. Necessary and sufficient conditions were not considered; if the process is successful, it applies to networks with all three types of element. A grounded three-port impedance 2 × 2 matrix, whose elements have a common denominator $D(p)$, is given.

Bordering elements are chosen to have as low degree as possible and to be such that $D(p)$ will be a factor of as many second-order determinants of the bordered matrix as possible. The bordered matrix is then inverted, and, when the method is immediately successful, the inverse determines a realizable grounded four-port. When it is not immediately successful (for example, when some of the powers of p are missing from elements of the original impedance matrix), a common factor may have to be introduced into the numerator and denominator of the original impedance matrix, and the bordering process is then repeated and the resulting matrix inverted to give realization as a grounded five-port, and so on.

Mr R. F. Hoskins (Telecommunications Research Laboratory, A.E.I., Woolwich) began the session on linear active network theory with *Flow-graph and signal flow-graph analysis of linear systems*. Essentially, this was a comparison of the signal flow-graph analysis introduced by S. J. Mason in 1954 with the flow-graph introduced by C. L. Coates in 1959. I was not alone among those present in thinking that the real question was whether *either* of these methods is needed. For the evaluation and manipulation of determinants and matrices, the techniques well known to mathematicians would appear to suffice, and be much simpler for those who have once mastered them. It may well be argued, however, that visual aids of this kind are an enormous help to those who are not mathematically inclined, enabling them to handle determinants and matrices at the sight of which they would otherwise shudder.

Mr A. W. Keen (Lanchester College of Technology, Coventry) discussed *Network synthesis in the non-reciprocal domain*. For such synthesis, a non-reciprocal element is needed in addition to the usual reciprocal elements. This element is called the unitor [long *i*], and is a three-terminal network such that there is no current entering at terminal 1, equal voltages at terminals 1 and 2, and equal and opposite currents entering the network at terminals 2 and 3. Two such unitors can act as a Unic (unit negative immittance converter). The general non-reciprocal two-port has equivalent T and Π representations each involving one unitor. Driving-point synthesis can be carried out with greater freedom and generality in the non-reciprocal domain; results thus obtained were compared with well known results obtained by reciprocal techniques. The unitor is also adequate for active transfer-function synthesis.

Dr W. Saraga (Telecommunications Research Laboratory, A.E.I., Woolwich) gave *A contribution to active* RC *network synthesis*. Any real rational function $F(p)$ can be expressed in the form $(Z_a - Z_b)/(1 - pZ_aZ_b)$; Z_a and Z_b are not unique, because $(Z_a + Z_c)/(1 + pZ_aZ_c)$ can replace Z_a and a similar expression with Z_b instead of Z_a can simultaneously replace Z_b. The simplest Z_a and Z_b are obtainable by solving the equation $F(p) = p^{-1/2}$; Z_a is then definable in terms of zeros lying in the right half $p^{1/2}$-plane and Z_b in terms of the remainder, and realization is achieved by arrangement of the impedances Z_a, Z_b, $1/pZ_a$, $1/pZ_b$ and a negative immittance converter. Results thus obtained are compared with those of other workers, and the new method proposed appears to be truly complementary to existing methods.

Non-linear theory

Professor Cherry opened the session on non-linear network theory with *Non-linear circuit theory by the methods of classical dynamics*. A resistive linear network was first illustrated in the form of adjacent non-overlapping rectangles with horizontal and vertical sides; vertical distances represented voltages, and horizontal distances currents; vertical lines in the diagrams represented meshes and horizontal lines nodes; areas represented power and diagonal slope represented resistance. Correspondingly, for a non-linear resistor network, the voltage/current relations are curves, but the way in which the rectangles fit together is essentially unaltered. Rectangle diagrams of this kind are only available for circuits having only one type of element (e.g. all resistors).

The total power dissipated in a linear resistor circuit is a stationary quantity; for non-linear resistor circuits it is the content G (or the co-content J), that is, the area lying below (or above) the non-linear voltage–current characteristic which is stationary; similar properties apply to non-linear all-inductor or all-capacitor circuits. The way in which the equations of Lagrange and Hamilton, originally formulated for dynamical systems, could be applied to non-linear electrical systems was considered in detail.

Lastly, Dr Ir. S. Duinker (Philips Research Laboratories, Eindhoven) discussed the *Search for a complete set of basic elements for the synthesis of non-linear electrical systems*. He proposed to introduce two new non-linear three-ports, the ' traditor ' for which

$$e_1 = -Aq_2i_3; \quad e_2 = -Aq_1i_3; \quad e_3 = Ad(q_1q_2)/dt$$

and the unitor (short *i*, and unrelated to Mr Keen's unitor) for which

$$e_1 = -Ai_2i_3; \quad e_2 = -Ai_1i_3; \quad e_3 = 2Ai_1i_2$$

where e_k and $i_k = \mathrm{d}q_k/\mathrm{d}t$ represent voltages and currents respectively, and A is a constant. These new elements can neither store nor dissipate energy, so the total power delivered to them is zero. The new elements can be combined with linear elements to simulate various non-linear entities (including for example the ideal diode) and it is believed (but not yet proved) that any passive non-linear system of given configuration, and with specified simple characteristics, can thus be simulated.

The last session was left open for participants' contributions, and consisted mainly of clarification—and even correction—of points which had arisen in the previous lectures. Long abstracts of the thirteen individual papers had been circulated beforehand, and it is intended that a complete written record of the proceedings (including discussion and contributions to the final open session) shall be published in due course by the Pergamon Press.

A slope method of approximation to the describing function

by **B. L. DEEKSHATULU** B.Sc.(Eng.), M.E., *Indian Institute of Science, Bangalore*

FOR NON-LINEAR ELEMENTS, DESCRIBING FUNCTIONS ARE frequently used to relate input and output of a non-linearity for sinusoidal input signals, and these functions are defined to be the ratio of the output fundamental to the input amplitude. In the slope method of approximation to the describing function, a gain concept is defined so that the non-linear elements may be replaced by a quasi-linear approximation (*3*, *4*). One of the objects of analysing a system is to determine whether there can be periodic oscillations, and if so what their amplitude and frequency will be. Sinusoidal analysis has been widely applied in predicting such oscillations and assessing the stability of non-linear control systems. The describing function approach is applicable to control systems of any order. Indeed, it usually tends to be more accurate the higher the order of the system. This is because the filtering properties against the harmonics are better in a higher-order system. Phase-plane analysis is restricted in use to second-order systems, or higher-order systems reducible to the second order.

Unfortunately there is no quick and simple means of arriving at even an approximation to the describing function of the most ordinarily encountered non-linearities. Prince (*1*) in determining the closed-loop frequency response of a non-linear system, introduced the concept of *equivalent gain*, and Bhatt (*2*) approximated a non-linearity with a number of linear segments with different slopes, evaluating the in-phase and quadrature components. For engineers, the physical understanding of the analysis of an example and the ease of interpretation of the result are of greater importance than mathematical rigour. Hence, in the slope method of approximation, mathematical analysis is considered an auxiliary tool. Every problem is attacked by the method most expedient in the particular case. Graphical methods appear to be the proper tools for solving non-linear problems, especially because they often provide a visible summary of conditions and changes of the solution with respect to any variation of the parameters.

Slope

The '*slope*' method provides a simple method for approximating the describing function. The input to a non-linear element is assumed to be sinusoidal. We assume also that the tangent of the angle subtended at the origin, by a point on the given non-linear characteristic curve corresponding to the input peak amplitude, represents a measure of the describing function. This measure is called simply the *slope*. The describing function is obtained by multiplying the slope by a factor called the *slope coefficient*, K, according to the definition:

$$\text{Describing function} = \frac{\text{Peak amplitude of fundamental output}}{\text{Peak amplitude of the input sinusoid}} \quad (1)$$

$$= \frac{\text{Peak amplitude of fundamental}}{\text{Output corresponding to input peak}} \times \frac{\text{Output corresponding to input peak}}{\text{Peak input amplitude}} \quad (2)$$

$$= \text{Slope coefficient, } K \times \text{slope} \quad (3)$$

The factor *slope* depends only on the point on the non-linear characteristic curve corresponding to the input peak, and the *slope coefficient* takes into account how this point is reached from the origin and therefore depends on the path or nature of the non-linearity.

To develop the method further, consider a simple non-linearity with dead band as shown in Fig. 1. For the positive cycle of the input sinusoid, it is sufficient to consider the positive half of the non-linearity. The peak input amplitude is represented by A. Imagine a variable point P to be moving along the non-linear characteristic corresponding to the peak of the input sinusoid A. When A is zero, P coincides with the point 0. As A increases P moves on the horizontal line $0a$ and the slope of the point P with respect to the origin is given by $\tan \alpha = 0$, indicating the gain to be zero. When A exceeds a, P follows the β slope line, $\tan \alpha$ increases and so the output also increases. In the limit, when $A = \infty$, $\tan \alpha$ equals $\tan \beta$ as is expected. Thus the *slope* of the variable point P is a measure of the describing function. It should be remembered that point P corresponds to the peak amplitude and not the different values of the input sinusoids. In this case

$$\textit{slope} = \tan \alpha = \beta(A - a)/A = (1 - a/A) \quad (4)$$

Given a non-linearity and the input sinusoid the *slope* can at once be determined. The shape of the non-linearity is taken into account by the *slope coefficient*.

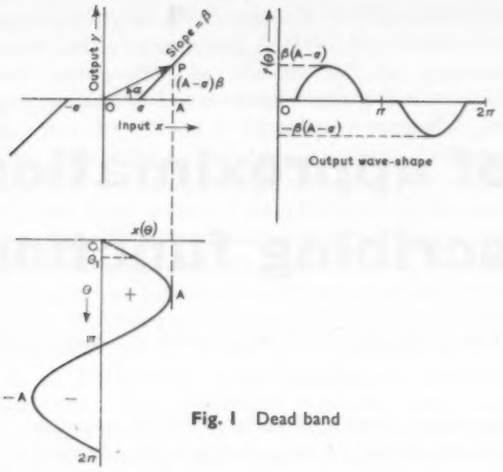


Fig. 1 Dead band

Slope coefficient, K

To obtain the *slope coefficient* one has to obtain a mathematical expression for the fundamental Fourier component in the output. To get an idea of the value of the slope coefficient and how it varies for some of the commonly encountered non-linearities the following examples are taken.

a SATURATION Referring to Fig. 2, the amplitude of the fundamental can be proved to be

$$b_1 = \frac{2\beta}{\pi}\left(\theta_1 + \frac{\sin 2\theta_1}{2}\right) A \tag{5}$$

The slope coefficient for saturation

$$K_s = \frac{2}{\pi}\left(\theta_1 + \frac{\sin 2\theta_1}{2}\right)\frac{\beta A}{a\beta} \tag{6}$$

$$= \frac{2}{\pi}\left(\theta_1 + \frac{\sin 2\theta_1}{2}\right)\frac{A}{a} \tag{7}$$

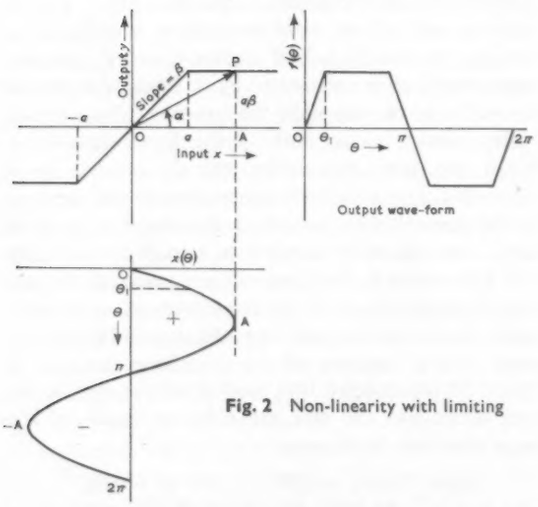


Fig. 2 Non-linearity with limiting

Thus the slope coefficient is independent of the slope of the path to clipping. K_s is evaluated for different amplitudes (A/a ratios) and is shown below.

A/a	1	2	3	4	5	6	10	∞
K_s	1·0	1·22	1·24	1·26	1·27	1·27	1·27	0

An average value of 1·25 can therefore be taken for K_s.

b DEAD BAND Referring to Fig. 1, the fundamental amplitude is given by

$$b_1 = (2\beta/\pi)\,(\pi/2 - \theta_1 - \tfrac{1}{2}\sin 2\theta_1)\,A \tag{8}$$

and the slope coefficient for dead band

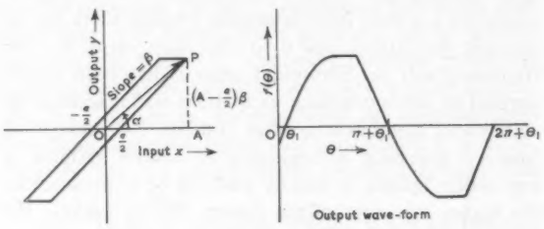
$$K_d = \frac{2}{\pi}\frac{\beta\,(\pi/2 - \theta_1 - \frac{1}{2}\sin 2\theta_1)\,A}{\beta(A-a)} \tag{9}$$

$$= \frac{2}{\pi}\frac{(\pi/2 - \theta_1 - \frac{1}{2}\sin 2\theta_1)}{1 - a/A} \tag{10}$$

K_d is also found to be independent of the slope β. The values for K_d are tabulated below.

A/a	1	2	3	4	5	7	10	∞
K_d	0	0·785 = 1/1·27	0·864 = 1/1·14	0·91 = 1/1·10	0·94 = 1/1·06	0·955 = 1/1·04	0·97 = 1/1·03	1

An average value of 0·91 or 1/1·1 may be taken for K_d.



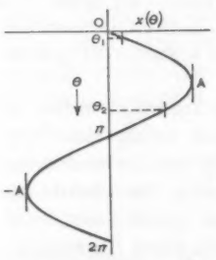


Fig. 3 Backlash

c BACKLASH Referring to Fig. 3

$$\text{Slope} = \tan\alpha = (A - a/2)/A = 1 - a/2A \tag{11}$$

The slope coefficient is given by K_b where

$$K_b = \frac{\sqrt{\left\{\frac{a}{\pi A}(a/A - 2)\right\}^2 + \left\{\frac{1}{\pi}[\pi/2 + \theta_2 + (1 - a/A)\cos\theta_2]\right\}^2}}{(1 - a/2A)} \tag{12}$$

where $\theta_2 = \sin^{-1}(1 - a/A)$ and is independent of the slope of the characteristic. The following table gives the values of K_b for different ratios of A/a:

A/a	1	2	3	4	6	10	∞
K_b	1·18	1·12	1·10	1·08	1·06	1·04	1

An average value of 1·1 can be taken for K_b.

In this case the describing function obtained from equation 3 gives b_1/A, corresponding to the sine fundamental in the output wave-form. The cosine fundamental, a_1, can be proved to be

$$a_1 = \frac{\text{area enclosed by n.l. characteristic}}{\pi A}$$

Hence the total describing function, with its phase angle, is given by

$$\sqrt{\left(\frac{a_1}{A}\right)^2 + \left(\frac{b_1}{A}\right)^2} \angle \tan^{-1}(a_1/b_1)$$

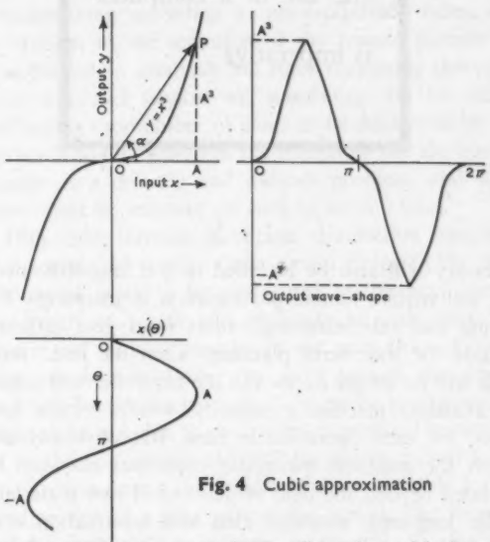


Fig. 4 Cubic approximation

d CUBIC APPROXIMATION A non-linearity with its output varying as the third power of its input is shown in Fig. 4. This is a case of symmetrical non-linearity, so the fundamental is given by

$$b_1 = 0{\cdot}75A^3 \tag{13}$$

and the slope coefficient for this non-linearity

$$K_c = b_1/A^3 = 0{\cdot}75 = 1/1{\cdot}33 \tag{14}$$

In this type of non-linearity the third harmonic amplitude is one-third the fundamental.

e ASYMMETRICAL NON-LINEARITY For asymmetrical non-linearities the slope is taken to be an average of the two slopes in the two opposite quadrants. In Fig. 5, the slope in the first quadrant is unity and in the third quadrant β, an average slope to be put in equation 3 is therefore $(1 + \beta)/2$. Similarly the output corresponding to the peak input is averaged and is equal to $[A(1 + \beta)]/2$. The fundamental amplitude is found by Fourier method to be

$$b_1 = \tfrac{1}{2}A(1 + \beta) \tag{15}$$

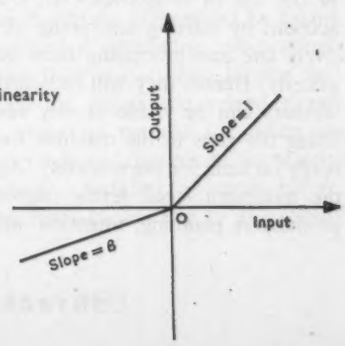


Fig. 5 Asymmetric non-linearity

Hence the slope coefficient

$$K_a = \frac{\text{Fundamental amplitude}}{\text{Average output corresponding to peak input}}$$

$$= [A(1 + \beta) \times 2]/[2 \times A(1 + \beta)] = 1 \tag{16}$$

In this case the describing function equals the slope given by

$$\text{describing function} = b_1 = \tfrac{1}{2}A(1 + \beta) \tag{17}$$

What the results show

If we consider the results of the above calculations we see that the *slope coefficient*, K, may be $\lesssim 1$, depending on the nature of the output wave-form; the *slope* value is always multiplied by the slope coefficient; and peaky or pulse-shaped outputs tend to give $K < 1$ while more regularly shaped outputs tend to give $K > 1$.

The extension of this simple method to highly non-linear (for thyratrons) or highly peaked non-linearities is open to question as it is not rigorously derived. Even for other non-linearities that are not included in this paper, the following empirical rules may help in determining the slope coefficient approximately.

1 If the output is constant over a wide range of θ at or near $\theta = \pi/2$ (as for saturation), the fundamental amplitude will always be greater than that constant value of $f(\theta)$ by an amount approximately proportional to the range for which $f(\theta)$ is constant. The slope coefficient is greater than unity (compare K_a and K_b with their corresponding output wave-forms).

2 If the output is approximately sinusoidal, or in the form of pulses spaced at intervals, and if these pulses are symmetrical about $\theta = \pi/2$ in the interval 0 to π (as in the case of dead band) then the slope coefficient is less than unity and the amount by which the fundamental amplitude and the output differ at $\theta = \pi/2$ is directly proportional to the width and inversely to the spacing of these pulses.

3 If the output is peaky and symmetrical about $\theta = \pi/2$ axis as in case (d); the slope coefficient is again less than unity but the amplitude of the fundamental in such cases is about $\frac{3}{4}$ of the height of the peak.

The gist of it

Given any non-linearity and an input sinusoid, the slope can readily be obtained. A rough estimate of the slope coefficient and whether it is greater or less than unity can also be discovered from the shape of the output wave-form. It is not necessary to plot the output wave-form to scale. The slope coefficient for many common non-linearities lies between 0·75 and 1·1.

Acknowledgement

The author is grateful to Dr P. Venkata Rao and Dr P. J. Bhatt for their helpful discussions on this article.

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PART 3

Production control and machine loading in a jobbing shop

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The de Havilland Aircraft Co. Ltd

Long-term plus short-term planning can lead to progressively higher levels of efficiency, but the use of a computer is imperative

In general, it is expected that the long-term planning will be a good deal less automatic than the short-term scheduling. The interaction between computer and human use, employing the machine as a planning aid, will probably be closer at the former stage. The programming, apart from certain rules for shifting the batches causing overloading, must include quick display of the position for the human planner, and facilities enabling him to try various courses of action and obtain quick answers. In this way, some of the limited and irregular factors could be dealt with, e.g. some scarcity of certain raw material, temporary overloading in the subcontractor's shop, unexpected delay in tool delivery, etc. During scheduling, certain parts will have priority over others, based mainly on objectives (5). In general, the tendency will be to have shorter time-cycles for expensive parts and to process them with higher priority in order to reduce the capital tied up in work-in-progress. An attempt will be made to even the load on the shop and to balance the additional expense of overtime and subcontracting, caused by overloading, against the cost of capital tied up owing to possible early machining in available gaps. Certain parts which are considered the key items in assembly will be scheduled with higher priority, and may also have a higher scrap allowance. The manufacture of spares will be planned, at this stage, as with any other order. Allocation of spares at the finished-part stage may be decided later, but priority will have to be clearly established to avoid confusion and shortages.

After establishing the long-term schedule, the timetable of requirements for b.o.f., raw material, subcontracting work and tools will be stated to the respective departments. It will be their duty to meet requests on time. They will check whether delays are likely and, if so, they will inform the data processing centre so that the schedule can be corrected.

The labour requirements and additional machinery necessary will also be included in the long-term plan; this will require human participation in planning. The buying and subcontracting orders must give sufficient latitude for short-term planning, when the fixed time-cycle will no longer apply and the computer will search for available machining capacity, within certain time limits, for each operation in turn. But obviously this search for available machining capacities may not be extended beyond the date of delivery of raw material.

The long-term machine load and information contained in mechanized files on finished products, assemblies and parts, b.o.f. or m/h on order on work-in-progress will be of invaluable help in answering sales inquiries. Where mechanized files exist, the feasibility of delivery dates could be determined automatically, with minimum delay.

Short-term planning

Short term machine-load scheduling will consist in the preparation of a list of operations to be performed within, say, next week. This will be done in relation to results obtained in long-term planning and using reverse scheduling; this time the fixed-length time-cycles will not be observed, but each operation will be allocated by searching for available capacity within the limited time, according to the priorities. The setting, movement and inspection times will be taken into account. The priorities will be based again on the maximum rate of return on the capital employed, as stated more explicitly in the list of objectives (5). (5)a will be taken into account by starting machining of expensive parts relatively late and processing them subsequently with high priority. Hence, they will be scheduled first. Twopenny washers can be made at any time, probably best by filling the gaps in the machine load, provided they are ready on time for the assembly. Again, when calculating the minimum stock levels supporting this scheme of production planning, attention will be focused mainly

on expensive parts. Objective (5)d will be taken into account by giving high priorities to the parts difficult to manufacture, where the probability of rejects is high. Some of the possible priorities are:

a Cost of the part up to the given operation.
b Delivery date.
c Number of operations to go.
d Total time of machining per component.
e Number of components in the batch.
f Cost of assembly to which the part belongs.

Exceptional cases, which cannot be accommodated within normal hours or within overtime, night-shift and subcontracting according to pre-established rules, will be brought to the attention of the human planner. It is important to establish the rules permitting the computer to cover almost all scheduling at this stage, minimizing the number of cases to be dealt with by the human. The interaction of the computer and the human planner is a delicate and difficult problem, and strict limits must be imposed on each to avoid chaos.

Thus, each foreman in charge of a section consisting of machines of similar types would be given the total amount of work to be performed in the next period, the length of which will probably be one week. To ensure the smooth passage of the part through more than one section during the same period, the weekly load will be subdivided into three parts. In this way, it ought to be possible to ensure that a part will be worked on by the first section early in the period, passed to the next section during the middle; and be available for the third section at a later part of the period. The foreman will be instructed to adhere, in general, to this subdivision, but will be able to change it under the pressure of unexpected contingencies.

This method seems essential where there are large average numbers of operation per part. Without the subdivision, the delay associated with each operation would be one period on average, swelling work-in-progress intolerably. On the other hand, the shortening of the period increases the amount of computing, printing and communication. It also limits the extent of the foreman's decision in sequencing. The latter factor is very important, because the whole idea of issuing the total load per period to the foreman is based on the philosophy that, owing to many disturbances and factors which could not be possibly taken into mathematical analysis, short-term sequencing is likely to be performed best by somebody directly in charge of a small part of the shop. The load released, therefore, must be sufficiently great to include potentially many choices, but it must not be too large for the human brain.

Optimum batch-size should be determined by taking the resulting manageability of scheduling into account. Ideally, both problems, that of optimum lot-size and that of optimum sequence, should be solved simultaneously, but there exists no method for doing so. Hence, the batch size must be determined separately, before even the long-term scheduling, as stated before.

Each section will be loaded according to its capacity and estimated machine utilization, but an additional tentative load must also be given to prevent idle time in cases of better-than-expected foreman's scheduling, and machining in less than standard times.

It is most important for the system to include the means of monitoring the progress, and, if necessary, modifying the plan accordingly. At the end of each weekly period, the operations originally scheduled for this period, but not completed, will be included in the next period's load, presumably with an advanced priority. Comparisons with long-term planning will be made periodically, and, if there is a serious discrepancy, additional subcontracting and overtime will be decided upon. The production plan must be *realistic* at all times if it is to impress the shop floor.

It is well known that the sequence of operations is not always immutable; sometimes it is more convenient to alter the sequence. This could not be taken into account by the computer in planning, and consequently, will be left for the shop supervision. It is thought that if only a small percentage of operations is performed out of normal sequence, this feature should not unduly disturb the planned schedule. Also, some operations on different batches require similar settings and, therefore, should be performed in succession. This will also be left to the discretion of shop supervision. Small internal orders from various sources will not be scheduled but spare capacity will be left in bulk for the purpose. The scheduling of rectifications will be largely manual; files obviously do not exist for this. Scheduling of re-works may be mechanized, as files are likely to be available.

The characteristic features pertaining to the scheduling of assembly work have been discussed in a previous section. The kitting lists will, of course, be prepared mechanically, and the perennial shortage of finished parts should be reduced to a minimum within the new system, and in any case known beforehand. The kitting list will also serve for inspectors as a checking list. A few assembly parts which will have to be machined additionally on occasions should not upset the machining schedule, though they will have high priority.

In many jobbing shops, a batch is tooled for the next operation immediately after the previous operation, disregarding the time when the former takes place. Tooling may consequently stay idle for a long time when it could be used for other jobs. Also, in cases when the specified tooling is not available, the project engineer may find suitable alternative tools, which are then issued. But a short time later these tools may be required for their proper job and then, of course, they are not available. All these difficulties should disappear when a proper machine loading schedule is provided.

It is hoped that in the proposed system the parts will stay on the shop floor for much shorter periods, and this should reduce the number of modifications on two counts: there will be more time available for the design, which, as a result, will be more complete, and there will be less time for the designer to change his mind. The

d.p.c. will be able to alleviate the modifications problem in two ways. First, when the modification of a part is proposed, the computing centre, having the topical information on the actual state of progress of all projects, will be able at once to assess which batches and assemblies will be affected by the modification by scanning all projects for the modified part. These effects can then be assessed in terms of the resulting delays and cost, arriving in this way at an estimate of the modification's impact. When the modification is decided upon, the d.p.c. will be able to issue the relevant orders.

Buying and sub-contracting

The unlimited capacity of outside firms will be assumed. The request for raw materials, b.o.f. and subcontract work may include an indication of the urgency for certain items, but the time-cycles of subcontractors must, of course, be taken into account during machine scheduling. In the case of foreseeable and unavoidable delay, the d.p.c. will be informed in advance and make suitable readjustments in further planning. The d.p.c. will be notified when components are received and when they have passed all checks. The first notification is required, among other reasons, to avoid unnecessary prompting of the supplier during delay between delivery and inspection. Issue of raw materials will be specified by the d.p.c. when scheduling subcontract work.

Salvage

After each machining operation, the computer will be informed of the amount of rejects. Hence, data will be available for a warning signal if the limit on scrap is rapidly approached. Thus, even before the scrap allowance is actually exceeded, the planner (presumably human in this case) will be able to decide whether another batch is needed, and, if so, order it, with high priority if necessary.

The rejected goods go to salvage, where it is decided whether they are rectifiable or to be scrapped. The d.p.c. may indicate how urgent it is to decide in any particular case. If the whole batch is scrapped, the d.p.c. will cancel the corresponding future machine load, and, if another batch is ordered, will schedule it in the normal fashion.

Stores

It is most important that, whenever anything is put into store or withdrawn, the computing centres be promptly notified. Only in this way will the computer's files correspond to actual stock levels. Castings and forgings are treated as raw materials; for perishable items the check-date could be stated by the d.p.c. as an instruction for inspection.

Once in stores, the items should be allocated according to d.p.c. instructions, so that they cannot be misappropriated for other work. However, actual kitting and cutting in advance is not thought desirable, mainly because labelling labour and large storage space are needed.

SIMULATION OF SYSTEM

Before putting the system into operation it ought to be thoroughly tested by simulation.

The model of the shop, including statistical distributions of the major kinds of disturbances, must be realistic, and, at the same time, not prohibitive in complexity. It is not at all clear how to reach a workable compromise. Still, it has to be done somehow, as the prospect of imposing an unproved, fairly detailed scheme on the factory is rather chilling. Also, it may be possible to calculate how good (economically) an optimum sequence would be, without actually establishing it. Then the simulation would show what the difference is between this optimum sequence and the sequences produced by our method. If the gap is small, this would constitute a sufficient proof that striving for an optimum system is uneconomical.

TOWARDS HIGHER EFFICIENCY

The ideas discussed above constitute, at best, only an embryonic stage in the design of the system.

There is little doubt that the employment of a computer will be imperative, as any effective system is bound to require the processing of an enormous amount of data in a very short time. It is also clear that initially the values for some basic parameters, like movement times, parts' time-cycles etc., will have to be assumed, although these parameters are themselves functions of the type of machine scheduling. Although the simulations may throw some light on the values of these parameters in the new system, the final check will be made when the system is in operation. Corrected values of the parameters will be used in subsequent calculations. The general philosophy ought to be to tighten control progressively, especially on machine load sequencing. This will be done, presumably, by issuing the total load to the sections more frequently, and restricting the foreman's choice in sequencing. Thus, the design of an automatic control system is seen as a dynamic function, continuously extending the scope, generating new problems by tentative solutions to the previous ones, and making the organization proceed in steps towards progressively higher levels of efficiency.

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End

DATA SHEET 25

Effects of adjacent piping arrangements on control valve characteristics

by **G. F. BROCKETT,** *Fisher Governor Co. and* **W. J. L. KENNEDY,** *Stone & Webster*

It has come to the attention of the authors many times that control valves are installed with little thought as to the effect which piping arrangements immediately adjacent to the valve will have on their performance. Process control engineers carefully size each valve and specify suitable plug characteristics. The actual installation layout is then turned over to piping designers, who in general give little thought to the control functions of the valve. It is also common practice not to allow for the pressure drop though the stop valves and associated piping.

It is a regrettable fact that in many instances the care used in specifying control valves in the engineering stages of a project, and the efforts of manufacturers to provide precise valve characteristics and capacities, are partially nullified by poor installation practices. In this data sheet the effects of several of the more common manifold arrangements on the control valve characteristics are investigated. It is hoped that those responsible for the selection of control valves will be encouraged to review the actual installation details.

Test conditions

In the test results which follow, the basic characteristic (stem travel/flow capacity) of the control valve is plotted for reference. In each case the characteristic is plotted for a stated pressure drop across the valve, which includes the pressure drop due to the two necessary reducers at the inlet and outlet flanges.

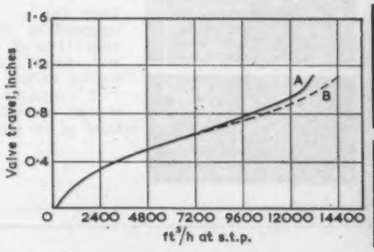
It is common practice to take the pressure drop across the entire control valve manifold as the pressure differential available for control. That is, if 10 lbf/in² drop is allowed for control, 2lbf/in² of this may be used in the piping immediately adjacent to the control valve. The authors have followed this practice in the test results given here; the control valve and its adjacent pipe fittings have been treated as a unit, and the pressure drop is that across the complete system. It seems obvious that a reduction in effective capacity of the control valve will result; the fact that this is obvious does not ensure that its effects will be compensated for. If it were not true that many control valves are oversized by duplication of safety factors, this effect would be more commonly noticed.

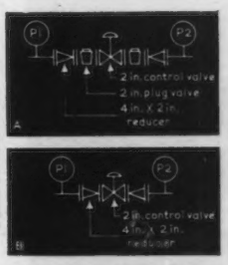
Figs. 1–15 show results obtained with a variety of piping configurations and pressure drops. Tests were carried out with 2in valves in a 4in pipe, and 4in valves in an 8in pipe. Both single- and double-ported valves were tested, and both air and water were used as test fluids. The conditions during each test are stated with the results. All the valves were throttle-plug globe.

For example, the first test manifold shown in Fig. 1 consisted of a single-ported control valve with a throttle-plug inner valve in a 4in line, with 2in plug cocks used as stop valves, and 4in by 2in concentric reducers. Pressures were taken at the inlet and outlet of the manifold. The plotted data represent test runs using air at 10lbf/in² inlet pressure with a 1lbf/in² pressure drop. The curve on the right represents the valve capacity in a straight 4in line with 4in by 2in reducers on the valve inlet and outlet. The installation of plug valves reduces the maximum capacity approximately 8·5%.

1

Valve size: 2in
Single port
Pipe size: 4in
Fluid: air
Inlet pressure: 10 lbf/in²
Pressure drop: 1 lbf/in²

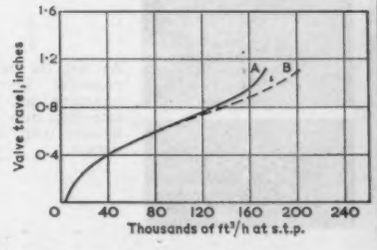


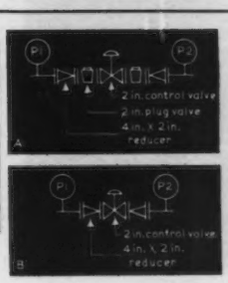


The inclusion of plug valves in the position shown reduces the maximum capacity by approximately 8·5%.

2

Valve size: 2in
Single port
Pipe size: 4in
Fluid: air
Inlet pressure: 100 lbf/in²
Pressure drop: maximum

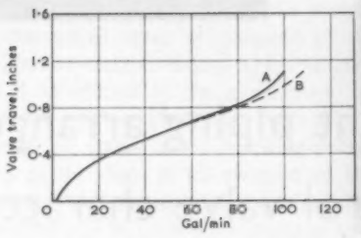


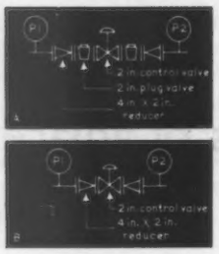


Arrangement is as test (1) with higher upstream pressure and increased pressure drop. Capacity reduced by approximately 13·5%. Intermediate upstream pressures and pressure drops show corresponding drops in capacity. Results with a double-ported valve were almost identical.

3

Valve size: 2 in
Single port
Pipe size: 4 in
Fluid: water
Inlet pressure: 100 lbf/in²
Pressure drop: 5 lbf/in²

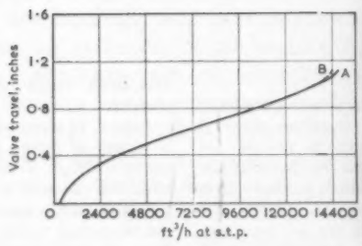


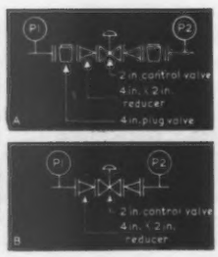


As tests (1) and (2) but using water instead of air. Capacity reduced by about 9%. Tests at other pressures and pressure drops, using both single and double ported valves, gave similar results.

4

Valve size: 2 in
Single port
Pipe size: 4 in
Fluid: Air
Inlet pressure: 10 lbf/in²
Pressure drop: 1 lbf/in²

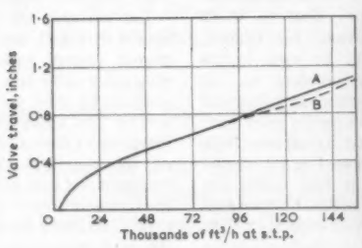


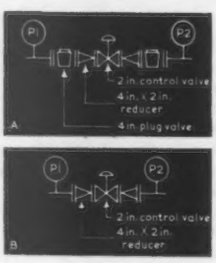


Similar to test (1) except that 4 in plug valves are used and the reducers re-located. Fittings have little effect on valve capacity or characteristic.

5

Valve size: 2 in
Single port
Pipe size: 4 in
Fluid: air
Inlet pressure: 75 lbf/in²
Pressure drop: maximum

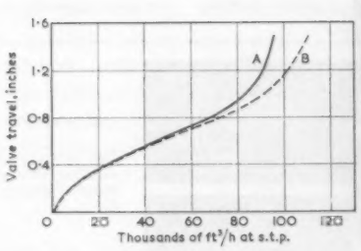


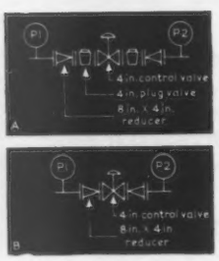


Similar to test (2) but with 4 in plug valves and re-located reducers. Little reduction in capacity, but change in characteristic over last 40% of travel. This change is thought to be caused by flow pattern in single-ported valve body, no similar results being obtained in similar tests with double-ported bodies.

6

Valve size: 4 in
Single port
Pipe size: 8 in
Fluid: air
Inlet pressure: 10 lbf/in²
Pressure drop: 5 lbf/in²

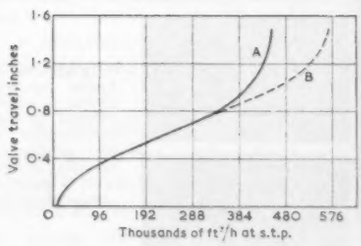


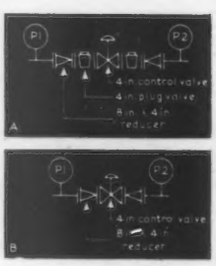


Tests (6) to (9) inclusive were intended to check the results of tests (1) to (5) for larger size pipes and valves. Test (6) is generally similar to test (1). Approximately 13·5% capacity reduction and large change in characteristic over last third of the stroke.

7

Valve size: 4 in
Single port
Pipe size: 8 in
Fluid: air
Inlet pressure: 75 lbf/in²
Pressure drop: maximum

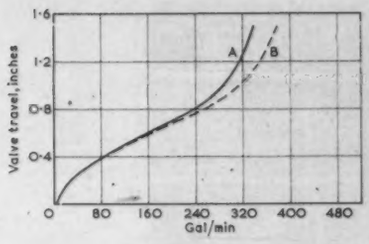


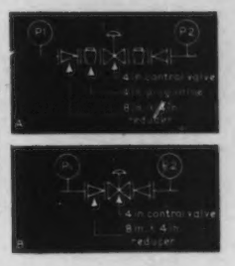


As test (6) but using high inlet pressure. About 21% capacity reduction and poor control characteristics over last third of stroke. Results with double-ported valve similar.

8

Valve size: 4in
Single port
Pipe size: 8in
Fluid: water
Inlet pressure: 100 lbf/in²
Pressure drop: 5 lbf/in²

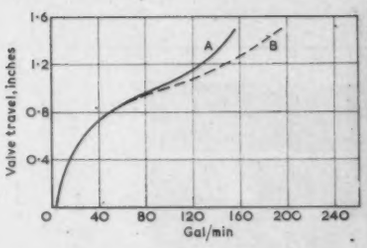


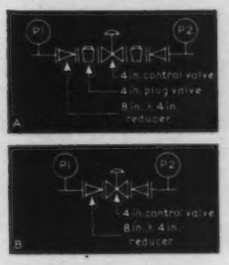


Similar arrangement to that of test (7), using water. Capacity reduction slightly over 10%.

9

Valve size: 4in
Double port
Pipe size: 8in
Fluid: water
Inlet pressure: 10 lbf/in²
Pressure drop: 1 lbf/in²

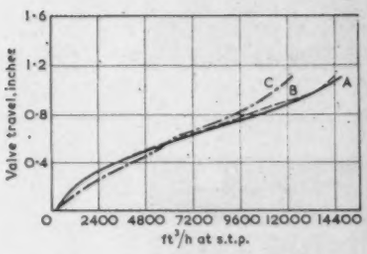


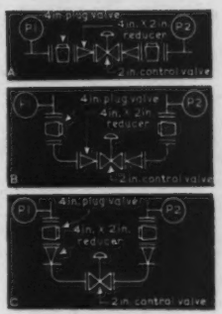


As test (8) with double-ported valve and lower pressure. Results similar to test (7).

10

Valve size: 2in
Single port
Pipe size: 4in
Fluid: air
Inlet pressure: 10 lbf/in²
Pressure drop: 1 lbf/in²

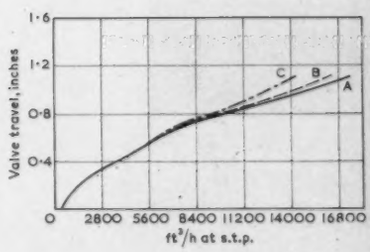


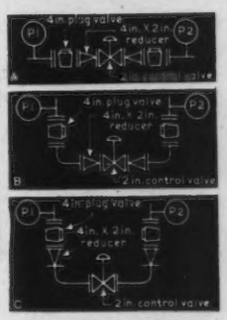


Test of the commonly-used 'U' type control-valve manifold, with 2in and 4in elbows. Capacity reduction with 2in elbows more pronounced, capacity being reduced by 17% and characteristic altered over whole travel.

11

Valve size: 2in
Double port
Pipe size: 4in
Fluid: air
Inlet pressure: 10 lbf/in²
Pressure drop: 1 lbf/in²

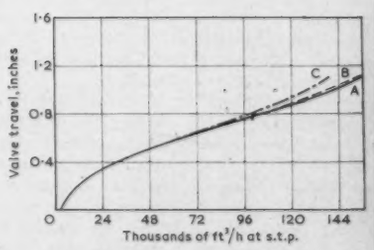


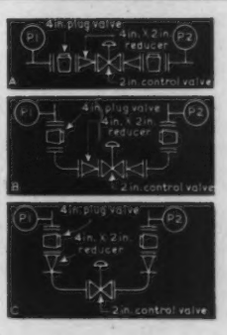


As test (10) with double-ported valve. Capacity loss is similar, but characteristic less affected.

12

Valve size: 2in
Single port
Pipe size: 4in
Fluid: air
Inlet pressure: 75 lbf/in²
Pressure drop: maximum

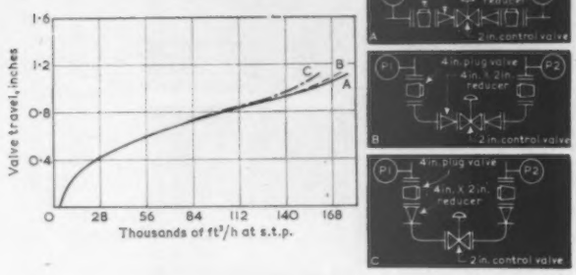


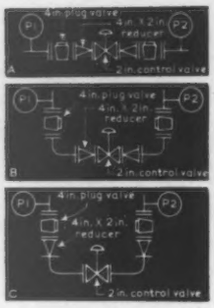


As test (10) but using higher pressures. Effects of fittings less marked.

13

Valve size: 2 in
Double port
Pipe size: 4 in
Fluid: air
Inlet pressure: 75 lbf/in²
Pressure drop: maximum

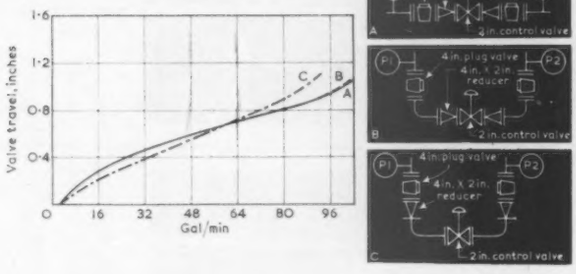


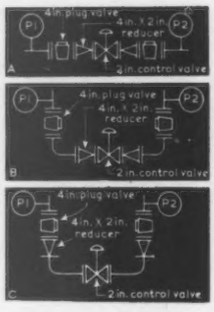


As test (11) but using higher pressures. Effects of fittings less marked.

14

Valve size: 2 in
Single port
Pipe size: 4 in
Fluid: water
Inlet pressure: 100 lbf/in²
Pressure drop: 5 lbf/in²

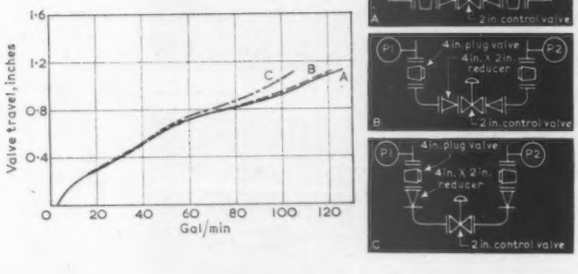


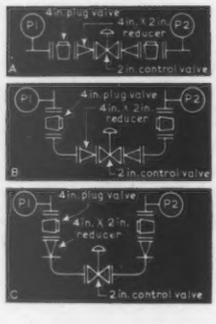


Similar to test (12), using water. Arrangement with 4 in elbows has little effect. 2 in elbows give almost straight-line characteristic.

15

Valve size: 2 in
Double port
Pipe size: 4 in
Fluid: water
Inlet pressure: 100 lbf/in²
Pressure drop: 5 lbf/in²





Similar to test (14), using double-ported valve. 4 in elbows have little effect. 2 in elbows produce capacity reduction similar to that obtained in test (14), but little change in shape of the characteristic.

CONCLUSIONS

While results of these tests in so far as capacity reduction is concerned could probably have been predicted, the changes in valve characteristic are not predictable.

The present tests used plug valves; other types of valves and fittings could have been used and the results obtained would then depend on the flow pattern and pressure loss characteristics through them.

It is common practice to reduce the size of the inlet and outlet stop valves, as well as to add elbows in the manifold. It can be expected that this will result in impaired capacity and characteristic. Shortage of time limits the test data which can be obtained in this field with a reasonable expenditure in time and money. It is believed, however, that these basic tests indicate several general points.

1 Arrangements which amount to a nozzle effect discharging into the body of a single-seated valve will alter its characteristic adversely.

2 Reduction from line size of inlet stop valves will affect characteristic and capacity. Thus, a saving in valve cost will require more pumping horsepower for the same flow rate.

3 If a shut-off and by-pass arrangement must be used around a control valve, the valve is best placed in a straight-through section. Rather tortuous manifolds are sometimes provided for control valves in order to obtain accessibility. The adverse effect on valve characteristic and capacity should be considered.

4 In gas service, the fact that critical pressure drop is available does not ensure that the valve capacity will be unaffected by pressure loss in the manifold.

Great care must be used in applying these results to other types of installations, particularly those involving high pressure drops, viscous flow and two-phase flow. Control valves sometimes develop discontinuities of great magnitude in their characteristics; insufficient care in selecting the piping arrangements around the control valve can magnify these problems greatly.

Pick-off

by 'UNCONTROLLED'

IN ITS LEADER last month, *Control* quoted from the speech made by Academician Trapeznikov at the opening of the first Ifac Congress in Moscow. Trapeznikov seemed to be appealing for international co-operation, and he suggested that progress in automatic control will depend considerably on 'contacts and the exchange of information between scientists and engineers in various fields and various countries'. Such a sentiment could not but be welcomed in a *Control* leader, and I too read it with approval. But afterwards, when I looked up the full speech in the published proceedings of the Congress,* I found an unwritten and ironical comment on Trapeznikov's words. There is a printed list of people who contributed papers, and the batches of western names-and-addresses mingle with blocks of bare names under the principal communist countries. How would the illustrious Academician like us to address our letters to the Soviet or Chinese participants? Surely they are not afraid of receiving capitalist circulars—unwanted mail can as easily be redirected to communist as to other waste-paper baskets.

AS IS COMMONLY THE CASE nowadays, a certain well known British instrument company recently obtained a licence to sell in this country a range of devices made in the U.S.A. I went along to look at these and was told by the sales engineers that these instruments were the 'Rolls-Royce' of their kind in the States. They were very nicely finished pieces of work; so I was the more surprised to find that (with one exception) they were all similar to home products—but at two or three times the price.

'And who in Britain do you think will buy these instruments?' I asked.

'Well, this has given us some headaches', came the reply, 'but you know, these things are used a lot at Cape Canaveral. It doesn't look as if it will be too hard to sell them to the Government'.

I OFTEN WONDER what compositors think about while they are at work on mathematical print. If it is as much Greek to them as it is to me, they must find it vastly more frustrating than the dullest of straight text. I hear from an unimpeachable source that, in an otherwise perfect printer's proof of an examination paper, the student was requested to '. . . determine the value of K_2 to satisfy the criterion $M_{max} = 1{\cdot}3$ under closed-shop conditions'. The feedback that influenced this compositor's transient response to servo theory was, one might say, linked to output, but not in the examiner's sense.

IN A WORDY BUSINESS, I am naturally sensitive to word usage. Publicity hand-outs can therefore make me wince literally as well as technically, but sometimes a touch of unconscious humour produces a happier reaction. A small joy the other day was a manufacturer's sheet announcing that his type-*X* device 'is made *against* the Ministry of *Y*'s Specification *Z*' (my italics). The thought of designers battling manfully against impossible ministerial odds reminded me of some inglorious affrays in my own past. In retrospect they are grimly funny, but they weren't at the time.

'WE REGRET THAT for security reasons (our own security) we cannot allow our names to appear, even in your distinguished columns': thus the three contributors of the manifesto which (slightly abridged) I reproduce below. I believe that these gentlemen are prepared to carry their public benefaction still further and to perform the administrative rites on the first few applicants for membership. The Editor has their address, and he tells me that he will be glad to pass on any correspondence to them.

THE INSTITUTION OF MEETINGS ENGINEERS

It has long been apparent that the arbitrary classification of engineers into Civil, Mechanical, Electrical, etc., although well established, is no longer relevant. More engineers than ever are making their contributions to industrial development through the medium of meetings. It is on his performance at meetings that the ability of an engineer is judged. Therefore it is believed that, in accordance with modern practice, only one classification of engineer is required, namely Meetings Engineer. The Institution of Meetings Engineers has been formed to further the interests of the profession and to encourage the use of meetings engineering techniques in the less progressive industries.

It has been proposed that the grades of membership within the Institution should be as follows:

Full Member (M.I.Meet.E.) Candidates for admission to the Institution as Full Member must have been employed as a Senior Meetings Engineer for at least five years. In that capacity they must be attending at least six meetings a week and serving as chairman of at least four. They must satisfy the Council of the Institution that not more than ten per cent of the meetings at which they have officiated have made any decisions. In addition, a candidate must convince the examiners that he is competent to disrupt meetings using any two of the following techniques: Temporary Absence, Personal Reminiscence, or Total Irrelevance.

Associate Member (A.M.I.Meet.E.) Candidates for this class of membership must be employed as Assistant or Junior Meetings Engineers. In the course of their duties they must be attending at least three meetings a week, not more than one such attendance being in a part-time capacity. They must take part in a practical examination at which they must convince the Council of the Institution that they are capable of producing a set of minutes that bears no resemblance whatever to the proceedings of the meeting.

Corporate Member This grade of membership is offered to companies which actively encourage the practice of meetings engineering. All companies registered in the United Kingdom automatically qualify.

Affiliate It is appreciated by the Council that large numbers of engineers, although prevented from becoming Full Members or Associate Members of the Institution by reason of the stringent qualifications required, nevertheless have occasion to apply meetings engineering techniques. Consequently, any person employed as an Exhibition Engineer, Conference Engineer, Discussion Engineer or Symposium Engineer may be a candidate for admission as an Affiliate of the Institution.

* *Automatic and remote control*, edited by J. F. Coales *et al* (Butterworths)

A monthly review — under basic headings — of the latest control engineering developments for all industries; especially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are interested in instrument and control systems

IDEAS APPLIED . . .

. . . to POSITION

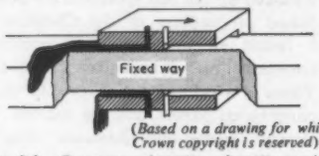
New hydraulic drive

As a result of studying the limitations of conventional methods of driving long precision movements, a new hydraulic technique has been devised at the Royal Aircraft Establishment, Farnborough. Though originally intended for linear movements of machine tools and contour-measuring machines, this technique would seem equally applicable to some special rotary movements, such as those used for positioning astronomical telescopes.

The object of the new technique is to achieve dynamic properties in the drive which are ideal for servo-control to a continuously varying demand. The sort of performance envisaged would permit a five-ton table with a stroke of six feet or more to be controlled by a magnetic tape to an accuracy of 100μin, at speeds up to 20ft/min and accelerations up to 1000ft/min/min. For this quality of control the requirements for the drive are very severe; they extend beyond the power unit and transmission to the points of attachment to the moving table and to the bed-plate. Table A compares three conventional drive principles with the new principle which has been called the 'efflux drive'. It is assumed in the comparison that very advanced designs of the conventional drives would be developed for this purpose, but there are nevertheless many limitations, the most serious of which are emphasized in the table.

In the table, the efflux drive is said to have no inherent stiffness. This means that there will be no mechanical resonances between the table and bed-plate, and in fact when the power is off, the table simply floats freely on the slideway. The control system designer may now choose the effective stiffness by adjustment of the position-feedback in the control loop, and, because thrust responds very rapidly to demand, high loop-gain is possible, and hence very high stiffness.

Fig. 1.1 shows the form in which a small prototype efflux drive has been tested. The fixed way, along which the table slides, is of rectangular section, and the moving table is a rectangular assembly completely surrounding the slideway. The table is supported and guided on this slideway by frictionless hydrostatic bearing pads. The only reason for the rectangular construction was for ease in making the prototype. A more practical arrangement might be a cylindrical way, or the usual T-section way, in which the table would not completely surround the way, but would be split at the bottom to allow the T-rail to be made integral with the bed. In the test model the fixed way is 7in wide by 5in high, and



(Based on a drawing for which Crown copyright is reserved)

Fig 1.1 Cut-away drawing showing principle of efflux drive

the table has four similar internal pockets, each 5·6in wide by 3·2in long, recessed to a depth of 0·006in. The clearance between table and fixed way around the slides and back of the pocket is 0·001in, so that the pockets effectively form two opposing pairs of wide but very shallow blind tunnels. Hydraulic fluid supplied at a pressure of 1000 lbf/in² to a two-way electro-hydraulic valve is switched to the left-hand pair of tunnels to generate thrust to the right (as depicted in Fig. 1.1), and to the right-hand pair of tunnels for thrust to the left, the fluid escaping freely from the open ends of the tunnels. The thrust generated is proportional to the rate of flow, and since the volume of fluid between the control valve and the thrust tunnels is small, this flow is established almost instantaneously with valve displacement. The reason for using upper and lower tunnels in pairs is to balance out the large forces, resulting from the fluid pressure in the tunnels, which tend to lift the table off the way. This small

	RAM	SCREW	RACK	EFFLUX
STIFFNESS	Poor, mainly because of dissolved air	Fair	Good	Inherently none
INERTIA	Low	Considerable, mainly in the long lead screw	Acceptable	Negligibly small
FRICTION	Appreciable, from piston–cylinder contact and rod glands	Moderate	Considerable, owing to the gear-box pre-load necessary to achieve stiffness. Tooth-form errors serious	None
END ATTACHMENT PROBLEMS	Moderate	Considerable	Slight	None

Table A Comparison of main features of conventional drives with those of the efflux drive

test model develops a thrust of 14 lbf in either direction at a flow of 1½ gal/min, using a hydraulic fluid of viscosity 65 centistokes. Scaling up to a five-ton table, and using the same light oil, one should obtain a thrust of 140 lbf at 7 gal/min. The stiffness to external loads should exceed 1 million lbf/in; that is to say, the table should yield less than a micro-inch for every pound of externally applied force.

It can be shown very simply that the thrust, T, obtained from an efflux tunnel, is given by

$$T = \tfrac{1}{2}PA$$

where P is the fluid pressure and A is the area of the back wall of the tunnel (see Fig. 1.2). The fluid-drag forces on the upper and lower tunnel walls are each equal to T. (Oil momentum is neglected since the rate of flow is small.)

The flow is given roughly by

$$0{\cdot}4\,Td^2/L\nu \text{ gal/min}$$

where T is the thrust in pounds, d the tunnel gap in thousandths of an inch, L the tunnel length in inches, and ν the kinematic viscosity in centistokes.

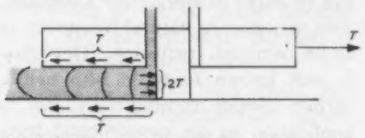


Fig. 1.2 Forces acting on fixed and moving members

The corresponding formula in C.G.S. units is

$$Td^2/4L\mu \text{ cm}^3/\text{s}$$

where μ is the viscosity in poises.

Because of errors introduced by leakage from the tunnel sides and temperature gradients in the fluid, these formulae should be regarded as giving only quick estimates of the flow. The formula for T is much more accurate.

A rotary drive is shown, in section, in Fig. 1.3. The pressure tunnel is contained in the journal bearing, in the form of a shallow recess extending around 340° or so of the internal surface of the bearing. In this arrangement the tunnel is closed at both ends, and torque is obtained by establishing a flow in the tunnel which may be visualized as rotating the shaft by viscous drag, or as requiring a pressure drop along the tunnel and hence different pressures at each end. Since the two ends of the tunnel are now situated back to back, and 20° apart, a net thrust results from this pressure difference, and the previous formulae apply, P now being the pressure drop. The oil enters either end of the tunnel depending upon the direction of the torque required, and is then vented to atmosphere from the opposite end *via* additional ports in the control valve. Although this form of closed-circuit flow is possible in principle for a linear motion, the practical difficulty of keeping the fluid free of dirt from the open slideway before it leaves

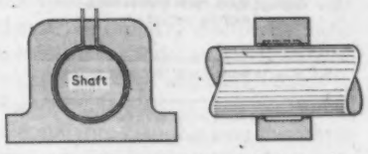


Fig. 1.3 Efflux principle applied to shaft drive

through the exit ports of the control valve might be prohibitive.

The pressure tunnel for the rotary drive could have been formed by turning a groove on the shaft, rather than as a recess in the internal surfaces of the bearing. In this case a small fixed tongue about 20° wide would protrude from the internal surface of the bearing into this groove, to form the two ends of the tunnel. An interesting point is that a closed circuit efflux drive of the type shown in Fig. 1.3 could be recessed into any shape of mating surfaces, and that it does not restrict their relative movement across the line of thrust. For instance, it could be built into a spherical joint, and arranged to rotate the joint in one or in several directions.

. . . to ILLUMINATION

Brightness control for neon lighting

by A. W. DAVEY, The General Electric Company Ltd

In view of the need for higher reliability and space saving on crowded instrument panels, as in modern aircraft, the use of instruments internally lit by neons deserves consideration. Besides being of rugged construction, and having low heat dissipation, neons have an advantage in colour, since the eye adapts more quickly to night vision after viewing red light. Their disadvantages are the low light output (which is now being overcome with the 'high-brightness' types recently introduced) and the difficulty of dimming them, as simply reducing the voltage causes failure of the neon to strike when the voltage is taken below the strike voltage.

IDEAS APPLIED . . .

The most practical way of dimming neons is to vary the conducting to non-conducting ratio, as in phase control, but since control is possible only over the part of the cycle where the applied voltage exceeds the strike voltage, a poor control-ratio is achieved. This can be improved to give the desired control ratio, however, if the phase-control frequency is made a sub-harmonic of the mains supply frequency, and control is exercised over a number of cycles of the supply frequency.

The scheme described here* controls

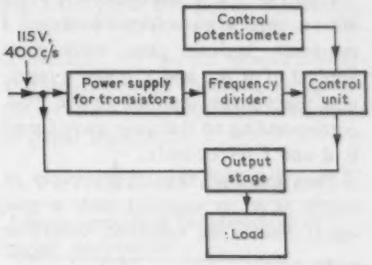


Fig. 2.1 Block schematic of dimming system

neons operating from 115V 400 c/s supply, and has a phase-control period of eight times that of the supply. A block schematic of the system is shown in Fig. 2.1.

Power is taken from the mains supply and is fed to the power-supply section, where it is converted into low voltage d.c. to feed all the transistor circuitry in the unit. Power is also fed from the 115V 400 c/s supply to the output section, which is shown in basic form in Fig. 2.2. It can be considered that, when the silicon controlled rectifier SCR_1 has a signal applied between its gate and cathode, points A and B are short-circuited and current can flow through the load.

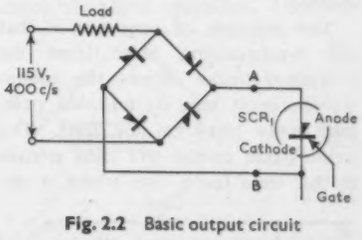


Fig. 2.2 Basic output circuit

When the gate signal is removed, and SCR_1 is in its non-conducting state, points A and B are open-circuited and no current flows through the load.

If control is to be carried out over a period of eight cycles, the gate

* Patent Applications Nos. 5035/61, 31384/61 34227/61 and 37169/61.

signal has to be maintained for nearly eight cycles of the supply to obtain maximum output, and maintained for only a fraction of a cycle in every eight for minimum output.

This is achieved by means of the mono-stable circuit of the control section, which has an adjustable mark/space ratio to vary the length of the gate signal, and an input trigger-pulse once in every eight cycles of the supply. The basic circuit of the mono-stable section is given in Fig. 2.3, and typical wave-forms are shown in Fig. 2.4. In Fig. 2.4, **a** represents the 115V 400 c/s supply wave-form; **b**, **d** and **f** represent typical gate wave-forms applied to SCR_1; **and c**, **e** and **g** represent the voltages applied to the load, corresponding to the gate wave-forms **b**, **d** and **f** respectively.

The point of the supply cycle at which SCR_1 is supplied with a gate signal has to be constant, otherwise

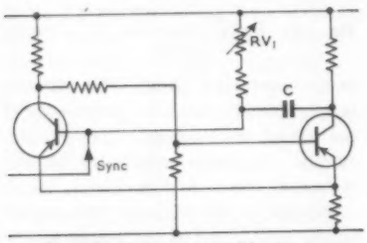


Fig. 2.3 Basic mono-stable circuit

when the neons are dimmed and have a very short conducting period, this period could occur at maximum or zero voltage, or drift between the two, thus modulating the light-output at the drift frequency. To avoid any such modulation, the mono-stable circuit trigger-pulse is therefore kept in synchronization with the 400 c/s supply by means of a frequency-divider.

The principle of operation is that the synchronizing pulse from the frequency-divider drives the mono-stable circuit into its unstable state, and hence turns on the load. The mono-stable circuit will then remain in this state for a time which is dependent on the setting of RV_1 and, on returning to the stable state, will turn off the load and await the next synchronization pulse.

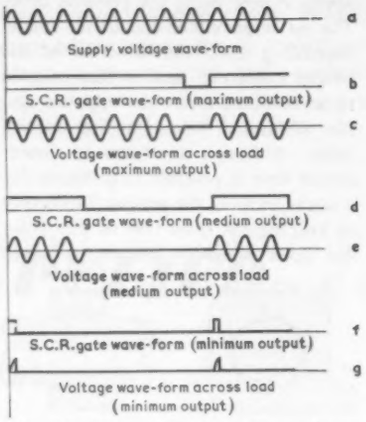


Fig. 2.4 Mono-stable output wave-forms in relation to load voltages

The removal of the gate signal from SCR_1 will not ensure that it turns off immediately, since the current through it has to be reduced at least to zero to do this. Therefore, since an immediate turn-off is essential to obtain the required control ratio, this is arranged by means of SCR_2, as shown in Fig. 2.5. Capacitor C_1 will charge to the peak value of the supply through MR_5; and if, when the gate signal is removed from Y and Z, a pulse is supplied to points X and Y causing SCR_2 to conduct, C_1 will discharge through the primary of transformer T_1. This will induce a current in the secondary, in opposition to the load current flowing, and SCR_1 will revert to the non-conducting state.

It should be noted that the load current flows through the bridge rectifier and SCR_1 only and, since the power supplied to the gates is sufficient to drive 50A s.c.r.'s under some conditions, a power handling capacity of over 5kW is obtainable with a control power of about 7W.

The complete circuit incorporates amplification of both gate pulses to ensure correct operation under all conditions of temperature, supply voltage limits and component variations.

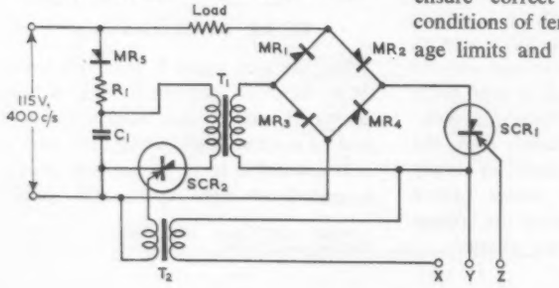


Fig. 2.5 Output circuit

. . . to VIBRATION

Novel method of generation

by P. G. MORGAN, University of Manchester

In a number of engineering problems, the mechanical vibration of a component is required, in order to determine its natural frequency of vibration, the presence of overtones, the damping qualities, *etc.* Specimens of certain shapes and materials can be excited by the usual mechanical methods of impact or bowing, or by electrical methods. In certain cases, however, none of the usual methods are applicable. For example, non-magnetic materials cannot be excited electrically, the component may be attached to other equipment which must not be jarred, or the vibration of a small item may be required.

An alternative method of inducing vibration in these circumstances is by the application of a solid block of carbon dioxide to the component; if certain conditions, to be described later, are fulfilled, then the component can be made to vibrate for a considerable period at its natural frequency, or at an overtone frequency. This effect is well known to those who handle carbon dioxide commercially, but its application as an experimental technique has not been developed. In general, the physical properties desirable in the body which is to be set vibrating are a suitable natural period of vibration, high thermal conductivity, high elasticity, and a small damping factor; for maintaining vibrations in small bodies, a high specific heat and specific gravity are necessary.

Tuning forks are readily excited by this means, the higher frequencies giving better results. Under certain circumstances a chattering sound is produced instead of a pure note, the result obtained depending to some extent upon the experimental techniques. Specimens in the form of a bar are also easy to excite, the two-node transverse vibration of a suspended bar being easily achieved. Of the engineering materials available, brass gives the best results, and in certain circumstances longitudinal vibrations of bar specimens of this material can be obtained.

An important engineering application is the vibration of metal plates, e.g. a single stage gas turbine rotor.

In this case there are a number of different modes of vibration which are difficult to calculate, and certain of which are difficult to excite by normal means. The carbon dioxide method is suitable for producing these different forms of vibration, and sand figures on the plate surface distinguish the positions of the nodes and antinodes.

Small objects, such as rings, are set in vibration when they are placed on the flat surface of a carbon dioxide block, and produce a note of a definite pitch. This represents a possible method of setting in vibration a small object which cannot be conveniently excited by other methods, but the comparatively short duration of the vibration demonstrates that it is only while the metal is losing heat to the block that the vibrations occur.

The ease with which vibrations can be excited in a given specimen varies markedly from day to day, and it appears that atmospheric conditions have some influence. In certain circumstances, water condenses on the metal at the point of contact with the carbon dioxide block, presumably because of the cooling of the air below the dew point. The sublimation temperature of carbon dioxide varies between −78°C and −93°C. It has been found that the density of commercial carbon dioxide has an important effect, and only blocks of high density cause vibration in metals. The range of density variation in carbon dioxide is wide, even within a given block, and this is a probable reason why the phenomena has not attracted more attention. In passing from a solid to a gaseous state, 1g of carbon dioxide takes up 140 calories, so that, in view of this large heat of sublimation, solid carbon dioxide can be conveniently stored for a considerable time in a vacuum flask.

From the experimental evidence, there is no doubt that the source of energy in the generation of vibration is the heat which is transferred from the solid body to the carbon dioxide during momentary contact of the two bodies. The thermal conductivity and mass of the body must be sufficient to ensure an adequate supply of heat, although the area of contact must be small. These conditions are fulfilled with tuning forks, metal bars, thick tubes and metal disks, and vibrations may be maintained in these bodies for a considerable period. With bodies of small mass, the source of energy is small, and consequently the vibrations cease fairly quickly, because of the fall in temperature. The efficacy of carbon dioxide in the production of vibrations is undoubtedly due to the fact that it sublimes, with the production of considerable gaseous pressure; this sublimation is greatly accelerated during the production of vibration.

The mechanism of maintenance of the vibration may be compared with that of an ordinary electrically maintained tuning fork, in which an electrical oscillation, originally excited by the vibrating body, is used to maintain the vibrations. In this case the vibrating metal determines the frequency, and the sudden gaseous pressure produced in a small cavity or groove at the point of contact of the two bodies maintains the vibration.

The excitation of vibration by solid carbon dioxide may thus prove to be a useful experimental technique, and there are several applications which require further study. One of these is its use as a Helmholtz resonator, which picks out the overtones in an irregular vibrating body. It may be used to determine the overtones in an irregularly shaped component, e.g. the determination of undesirable resonances in small machine components or in electrical plate condensers.

. . . CONDUCTIVITY

Measurement of moisture content of paper

One of the variables which has to be measured in paper manufacture is the moisture content of the paper. Though there are established methods of doing this, one being by inferring moisture content from conductivity, these are generally subject to errors caused by variations in the paper thickness. A method of overcoming this difficulty has been developed by the Wiggins Teape organization. The method is based on conductivity measurement, but uses an electrode system (Fig. 3.1) which automatically compensates for changes in thickness.

Several flexible metallic strip-contacts are mounted above the paper, and a continuous roller contact underneath. Alternate strip-contacts, and the roller, are connected to one of the input terminals of the conductivity meter, and the remaining strip contacts are connected to the other input terminal. The resistance paths being measured thus fall into two classes: (a) those between adjacent strips, and (b) those between one set of strips and the roller. The resistance of class (a) paths decreases with increasing thickness of the paper, while the resistance of class (b) paths increases. It has been

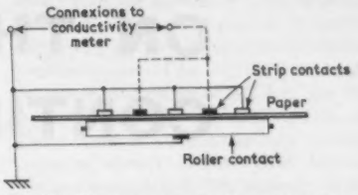


Fig. 3.1 Contact arrangement to compensate for variations in paper thickness

found that, by correct proportioning and spacing of the contacts, the equipment can be made virtually insensitive to paper thickness.

. . . to TEMPERATURE

Alarm operation independent of meter movement

In most temperature indicators which have to operate alarms, the signal is initiated by the physical movement of the instrument pointer (e.g. by direct contact or photo-electric means). In the Drayton–Southern 'Omiguard' indicator, a simple form of direct electrical operation is used. Essentially, the system comprises a conventional Wheatstone bridge network (Fig. 4.1) working from the resistance thermometer T, plus the resistance R with variable tapping P. P is adjusted until the current through the detector reverses at the desired alarm temperature. Reversal of the current is detected by a sensitive relay which initiates the alarm action.

A test unit is built into the equipment, which unbalances the bridge to check the alarm operation. The ther-

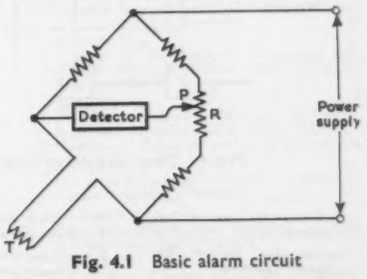


Fig. 4.1 Basic alarm circuit

mometer used is of sufficiently high resistance to provide the necessary power without amplification. A similar system can be used for pressure indication and alarm, using a suitable pressure/resistance transducer.

CONTROL ON THE CONTINENT

Digital control for inter-connected power systems

In modern inter-connected power systems, where transfer of power between two supplies is often according to a fixed schedule, some form of control of frequency and power-transfer is a necessity. For many years electromechanical controllers have rendered excellent service in this application. However, in the process of expanding system control, circumstances are often encountered where stipulations regarding the measuring accuracy of the controller, and the precision with which the output or 'actuating' values are formed, are more easily fulfilled by purely electronic means. Analogue methods of control being often limited in attainable accuracy, Brown Boveri & Co. Ltd, Baden, Switzerland, has recently developed a digital controller which offers high accuracy and flexibility (*1*).

The first of a regular series of reports from *Control*'s special Continental correspondents

The controller is designed for either combined power-frequency control or for individual power and frequency control. It is of the proportional-plus-integral type where the output correcting value of the controller is given by the following equations as applied to load frequency control:

$$Y = C_P(\Delta P + K\Delta f) + C_I\int_0^t (\Delta P + K\Delta f)\,dt$$

(combined power-frequency control)

$$Y_1 = C_P[\Delta P + (C_I/C_P)\int_0^t \Delta P\,dt]$$

(power control)

$$Y_2 = C_P K[\Delta f + (C_I/C_P)\int_0^t \Delta f\,dt]$$

(frequency control)

where:

Y = output 'correcting value' in %,
ΔP = deviation in tie-line power, in MW,
Δf = deviation in frequency, in c/s,
K = frequency aid to the power control in MW per c/s,
C_P, C_I are controller constants.

A block diagram of the digital controller is shown in Fig. 1. The controller is made almost completely of three fundamental circuits: Schmitt triggers, bi-stable circuits, and gates. It is fully transistorized and consists of functional units in the form of printed circuits.

Essentially, the controller performs two functions: measurement and conversion.

Measurement

The line frequency of 50 c/s if first multiplied to 500 kc/s and then counted over a 'count-in interval' of 0·1 s, giving an accuracy of ± 0·001 c/s (± 0·002%). The instantaneous value of the tie-line power is introduced into the controller as a frequency by the telemetering system. The power, telemetered in the form of a frequency, is converted and multiplied, bringing it into the same range as the multiplied line frequency, and measured in the same way as the mains frequency.

Pulses from the frequency multiplier are counted into the 'desired-value register'. Normally it takes 100 ms to count 50,000 pulses (corresponding to a desired mains-frequency value of 50 c/s). The difference

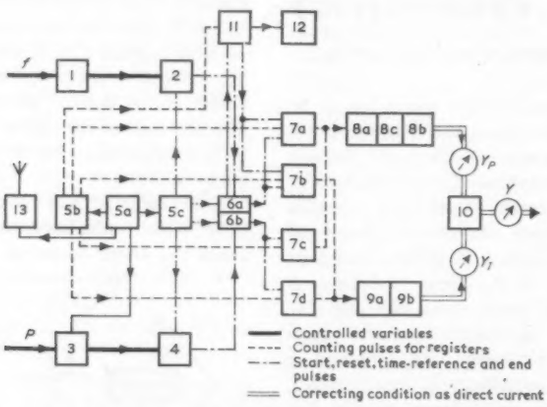


Fig. 1 Block diagram of a digital power-frequency controller

1, multiplier for system frequency
2, desired-value register for system frequency
3, frequency converter and multiplier for telemetering frequency for tie-line power
4, desired-value register for power
5a, 100-kc/s frequency standard
5b, counting frequencies
5c, time-base
6a, pulse evaluation for frequency
6b, pulse evaluation for power
7, pre-registers
a, proportional, for frequency
b, integral, for frequency
c, proportional, for power
d, integral, for power
8a, proportional register
8b, digital-to-analogue converter
8c, holding register
9a, integral register
9b, digital-to-analogue converter
10, output amplifier
11, Δf register
12, Δf indicator
13, monitoring receiver
f = system frequency
P = tie-line power (as telemetering frequency)
Y = correcting condition (controller output)
Y_P = proportional fraction of Y
Y_I = integral fraction of Y

between the time actually needed for 'counting-in' and the reference time of 100 ms is a measure of Δf. Time-base is obtained from a 100 kc/s magnetostriction oscillator, whose accuracy and stability are of the order of 10^{-7}. The settings of K are obtained by dividing the pulses counted in, giving (1, 1/2, 1/4, 1/8 . . .)f, and by using two counting frequencies in the ratio 2:3 (333 kc/s and 500 kc/s). Integration is obtained by successive additions.

Conversion

A digital-analogue converter changes the values of

$C_P(\Delta P + K\Delta f)$, and $C_I \int_0^t (\Delta P + K\Delta f)\, dt$,

which are stored in 'hold registers', into the analogue output Y in the form of a direct voltage across a resistance. The output is amplified in a d.c. amplifier, and the amplified signal actuates the main hydraulic servo-motor of the turbine governor through an electrically operated valve.

Such a controller has been in service in the Lavorgo power station of the Aare-Tessin Electricity Co. since June 1959. A second controller is operating in the generating station of the Elektrizitäts-gesellschaft, Laufenburg, Switzerland. Since March 1960 this has been used to control the transfer of power between the Swiss system and an adjoining network.

Stability of a sampled-data quantized system

The development of computer controls has lead to closed-loop systems which contain simultaneously linear, sampling, quantizing and logical elements. Published studies on stability analyses of such systems are quite rare. Recently, Senouillet and Guichet (*2*) have studied a position servo-mechanism containing two quantizers, one sampling and one hold element, and one second-order linear element (Fig. 2). A complete

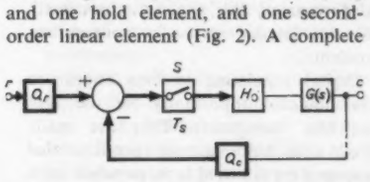


Fig. 2 Block diagram of a sampled and quantized servo-mechanism

Q_r, encoder converting motor position c to discrete value
Q_c, digital comparator computing the difference between the digital reference r and the encoded signal c
S, sampler with sampling period T_s
H_0, hold element
$G(s)$, linearized transfer function of the motor,

$$G(s) = \frac{K}{s(1 + \tau s)}$$

— analogue signals
— digital signals

solution of the problem is given in this paper, together with numerical examples, and reliable conclusions are drawn.

The analytical procedure used can easily be extended to similar problems, for instance, problems of computer control using an optimizing policy. The procedure may be summarized as follows:

1. Use Kalman's 'state-space' notation to represent in a unified manner the various elements of the system. The necessary and sufficient stability conditions are obtained by determining whether or not the eigen values of the transfer matrix have a modulus less than one. The conclusion is: if the non-quantized but sampled system is stable, then the quantized and sampled system is also stable. Therefore, the problem reduces to one of examining the behaviour of the system-error between two quantum values (the state of the system around the steady states).

2. For this, the quantizer is considered as a tri-stable $(-q, 0, +q)$ element. Phase-plane and describing-function methods can therefore be used to find necessary and sufficient non-oscillatory conditions of the error.

New field-effect semiconductor tetrode

The idea of a unipolar field-effect transistor was originated by Shockley, and a device based on Shockley's original idea has been studied in America by Dacey and Ross. Other devices of this type, but having a somewhat different structure, have been studied in France. One, known as the Alcatron, has been produced by the research laboratories of the Compagnie Générale de T.S.F., in collaboration with the Centre National d'Etude des Télécommunications (*3*). This device has an annular construction in which the two grids have been separated. The second and larger grid improves power dissipation and modifies the equivalent circuit at high frequency. The advantages of the device appear to be the following:

1. It is possible to increase the maximum frequency of such a field-effect device without losing the ability to dissipate power.

2. The maximum frequency may be increased by making reductions in a single dimension.

3. Minority carriers do not play any important role, and no storage effects are present. Oscillators having a frequency of 12 Mc/s and delivering an output of 1 W have been constructed using the Alcatron.

Your European Correspondents

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3. Grosvalet, J.: 'Etude d'un Nouvel Elément Tétrode à Effet de Champ: l'Alcatron' (Study of a new field-effect tetrode: the Alcatron), *L'Onde Electrique*, 1961 (Feb.), pp. 114–122

Ifac in Basle

The second congress of the International Federation of Automatic Control (Ifac) is to be held in Basle in September 1963, organized by the Swiss Association for Automatic Control. The first congress, which took place in Moscow in the summer of 1960, attracted world-wide interest and support in control engineering circles*. British authors wishing to present papers at the 1963 congress should contact the Secretariat of B.C.A.C., c/o The Institution of Electrical Engineers, Savoy Place, London, W.C.2. Authors in other countries should contact their national member organization. The addresses of the European member organizations are listed below. In most cases, the final date for submission of papers is June 1, 1962.

CONTINENTAL IFAC MEMBER ORGANIZATIONS

AUSTRIA
Österreichisches Produktivitäts-Zentrum, Österreichischer Arbeitsausschuß für Automatisierung, Renngasse 5, Wien I

BELGIUM
Institut Belge de Régulation et d'Automatisme, Secrétariat permanent, 98, chaussée de Charleroi, Bruxelles

BULGARIA
Bulgarian National Council of Automatic Control, 12, Narodno Sabranie sq., Sofia

CZECHOSLOVAKIA
Ustav Teorie Informace a Automatisace, Ceskoslovenská Akademie Véd, Zitna 28, Praha 2

DENMARK
Dansk Ingeniørforening, 29, Vester Farimagsgade, København V

FINLAND
Finlands Regleringstekniska Sällskap, c/o EKONO, E. Esplanadi 14, Helsinki

FRANCE
Association Française de Régulation et d'Automatisme, 19, rue Blanche, Paris 9e

HUNGARY
Nemzetközi Automatika Szövetség Magyar Nemzeti Bizottsága, Magyar Tudományos Akademia, Nádor utca 15, Budapest V

ITALY
Consiglio Nazionale delle Ricerche, Commissione italiana per l'automazione, Piazzale delle Scienze 7, Roma

NETHERLANDS
Koninklijk Instituut van Ingenieurs, Sectie voor Regeltechniek, Doorniksestraat 3, 's Gravenhage

NORWAY
Norsk Forening for Automatisering, Kronprinsensgate 17, Oslo

POLAND
Polski Komitet Pomiarów i Automatyki Naczelna Organizacja Techniczna, w Polsce, ul. Czackiego 3/5, Warszawa

ROUMANIA
Comisia de Automatizare, Academia Republicii Populare Romine, Calea Victoriei 125, Bucuresti

SWEDEN
Svenska Centralkommitten för internationella ingenjörskongressor, c/o Svenska Teknologforeningen, Brunkebergstorg 20, Stockholm

SWITZERLAND
Schweizerische Gesellschaft für Automatik, Sternwartstraße 7, Zürich 6

TURKEY
Türk Otomatik Kontrol Kurumu, Istanbul Teknik Universitesi, Istanbul

U.S.S.R.
Nazionalny Komitet SSSR po Avtomaticheskomu Upravleniu, Kalanchevskaja ul. 15-a, Moskva 1-53

YUGOSLAVIA
Jugoslovenski Komitet za Elektroniku, Telekomunikacije, Automatizaciju i Nuklearnu Tehniku, Terazije 23, Beograd

* See Control, August 1960, pp 84–96 and September 1963, pp 92–98

Our American correspondents' contribution this month includes a report on the A.S.M.E. Fall Textile Engineering Conference

Look at America

Digital speed-regulation

Perhaps one of the best known of all feedback control systems is the analogue speed-regulating system. The inherent problem with such a system is long-term drift, and its associated effect on the limits of accuracy which may be achieved. Usually, very careful design of components and control of ambient conditions are necessary before drift can be reduced to a reasonable level. In a paper presented at the recent Joint Automatic Control Conference, Dobbie and Fox (*1*) discuss a digital speed-regulating system capable of providing accuracies and flexibility beyond that obtainable by today's analogue devices. The use of digital signals in the reference, feedback, and error-detection circuits virtually eliminates the problem of drift associated with analogue circuits.

The structure of a digital speed-regulator is illustrated in the block diagram (Fig. 1). A fixed pulse-rate from the crystal oscillator serves as the basic reference for the digital system. Pulse-rate is divided in the reference-setting circuits by binary-coded decimal counters. This pulse-rate from the dividers is directly proportional to the speed required. A pulse tachometer connected to the drive motor gives a feedback pulse-rate which is proportional to the motor speed. The feedback and divided reference pulse-rates are compared in the coincidence pulse canceller, where pulses occurring at the same time are cancelled from both feedback and reference lines. After leaving the coincidence pulse canceller, the feedback and reference pulses are fed to the speed and position circuits. An alternate pulse canceller and 'up' and 'down' gates provide a d.c. signal proportional to the speed error. A reversible counter and a digital-analogue decoder provide a d.c. signal which is proportional to the position error. Output signals from the speed and position circuits serve as signal inputs to the amplifier. Dobbie and Fox have designed and successfully tested a digital speed regulator with an adjustable-voltage d.c. drive.

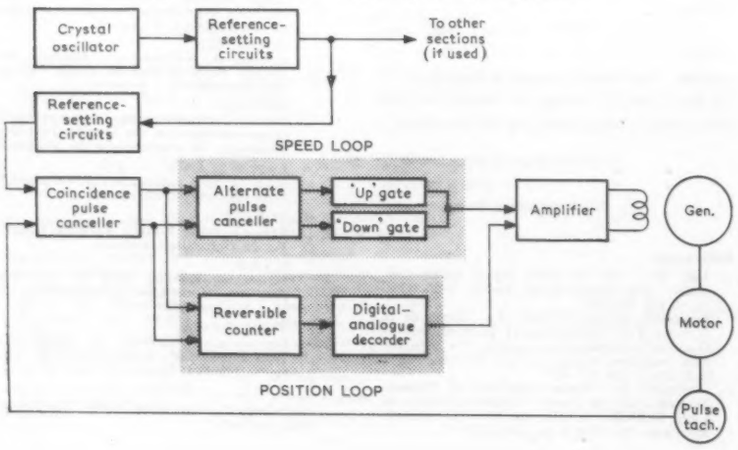
THIS MONTH

Speed control
Textile conference
Process dynamics

In an A.I.E.E. North Eastern District Meeting, R. R. Potts (*2*) described a similar digital speed-regulating system. (Unfortunately this paper was not available for detailed review by your correspondents.)

Digital regulating systems appear to offer unusual opportunity for use with 'on line' computers. They are easily fitted with automatic or pre-scheduled programs on punched tape, punched card, or magnetic tape.

Fig. 1 Block diagram of digital speed-regulating system



A.S.M.E. Textile Engineering Conference

The attendance at this year's conference (held at the Massachusetts Institute of Technology, 1–2 Nov.) was considerably greater than had been anticipated. Of the two hundred people present, almost one third were from the management sector of the textile industry. This year's theme, 'Automation and Its Potential for the Textile Industry', proved to be an excellent one, and brought forth eleven

speakers who gave papers* on a number of vital aspects of development in the textile industry. The program was organized in three Sessions as follows: Session I, Engineering aspects of process control (4 papers); Session II, Application of automation to textile operations (4 papers); Session III, Techniques useful in an automated textile organization (3 papers).

The conference was started off by a message of welcome from Dr Gordon S. Brown, Dean of Engineering at M.I.T., who stressed the need to consider labour problems and the disposition of human talents in the future development of automation. Session I dealt with basic problems such as dynamic behaviour of textile materials, interactions of fibres and processes, effects of fibre properties on processes, and the need for understanding of basic processes in the application of automatic control concepts to them.

Session II revealed how automation has been taking place in certain textile operations and included work on processing actions in the manufacture of worsted serge, continuous processing of textiles in dyeing and finishing operations, automated textile machinery, and recent foreign developments in automated spinning and preparatory equipment.

Session III dealt with the selection and training of personnel for automated textile mills, production scheduling by electronic computers, and operational research in the textile industry.

In a keynote speech at a banquet in the evening of 1 November, L. H. Hance, President of the Institute of Textile Technology, Charlottesville, Virginia, summed up the thoughts of many of those present when he pointed to the rising costs of labour and materials alongside a relatively constant price for finished textile materials, and expressed the view that the textile industry would be able to survive only through the best possible future use of automation.

By way of background, it should be noted that the American textile industry has been feeling increased competition from foreign sources, and that it has been given a better depreciation allowance by the government with the hope that this will help provide incentive to modernize equipment and improve processes.

Process dynamics

A seemingly perennial problem which faces the control engineer is that of having an inadequate understanding of the plant or process to be controlled. Certainly, the level of understanding of process dynamics has been overbalanced by the degree of sophistication achieved in control theory and in schemes for controlling the 'little understood' process. Nevertheless, control experts are becoming more cognizant of this apparent overbalance. Considerably more attention is being given to efforts aimed at establishing adequate theoretical models for a wide variety of real processes. Organized efforts to evaluate the state of knowledge of process dynamics in relation to equipment design have been made in the past by the Research Subcommittee of the Instruments and Regulators Division of the American Society of Mechanical Engineers (*3*).

Several contributions to the understanding of plant and process dynamics were made at the recent Joint Automatic Control Conference. A convenient collection of transfer functions for various types of heat exchangers was presented in a paper by Hsu and Gilbert (*4*). Most of the mathematical models described have appeared previously in the literature. However, the well organized mathematical description and classification of several basic types of heat exchanger is commendable.

In another well organized J.A.C.C. paper, Fan and Ahn (*5*) discuss tracer dispersion in a fluid flowing through a tubular vessel. Two particular cases are considered; namely, no chemical reaction and a first-order chemical reaction of the tracer. Using the classical diffusion model and the assumption that only dispersion in the axial direction is significant, a material balance with respect to the traceable component is shown to yield the following differential equations:

$$\frac{\partial C}{\partial t} = \bar{E}\frac{\partial^2 C}{\partial z^2} - u\frac{\partial C}{\partial z} \quad \text{(no chemical reaction)}$$

$$\frac{\partial C}{\partial t} = \bar{E}\frac{\partial^2 C}{\partial z^2} - \bar{u}\frac{\partial C}{\partial z} - kC \quad \text{(first-order chemical reaction)}$$

where z = axial direction co-ordinate, C = concentration of tracer, t = time variable, $\bar{E}$ = average value of axial mixing coefficient (determined empirically), $\bar{u}$ = average flow velocity, k = reaction rate constant.

From these basic describing equations, rigorous and systematic analytical derivations are made of the dynamic response of the tubular flow system with and without tracer reaction. Results are presented in concise, tabular form for sinusoidal, impulse, step, ramp, and parabolic inputs of the tracer concentration for each of three sets of typical boundary conditions.

The extension of the classical diffusion model to more complex systems, where two or more space variables are significant, leads to multi-dimensional, nonlinear partial differential equations which present considerable mathematical difficulties. Likewise, the classical procedure of making a detailed hydrodynamic solution of the system, from the Navier-Stokes equation, leads to insurmountable mathematical difficulties for the more complex cases. It is found that, in many of the more complicated cases, the flow system can be divided approximately into two types of region—a live-flow region through which the bulk of the throughput passes, and a number of relatively dead-flow regions which have only limited interchange of fluid with the live region. Using this approximate concept, Adler and Hovorka (*6*) have formulated a finite-stage model for a tubular flow reactor which may include end effects, dead volume, baffles, etc. The formulated model uniquely determines a so-called 'residence-time distribution' with four parameters. Residence-time distributions quantitatively describe the variation in holding times when a fluid stream passes through a system. An r-t distribution is readily determined experimentally by injecting a quantity Q of tracer instantaneously in the entering stream and measuring the resultant concentration v. time curve in the exit stream. Experimental r-t distribution data (i.e. impulse response) are necessary for the evaluation of the four model parameters. Adler and Hovorka outline a technique whereby the r-t distribution derived from the model can be fitted very closely to the experimental data. The convenient use of the model and the technique outlined is limited to highly asymmetric r-t distributions, unless a digital computer is available. The diffusion model is more easily used where symmetric distributions are present. The finite-stage model and its r-t distribution should be very useful for a wide variety of continuous, perfectly-mixed chemical reactors. Apparently the form of the model is also well suited to both analogue and digital computation. It has been suggested by others (*7*) that the model could be especially useful as an approximate representation of partially mixed chemical reactors, in control schemes which optimize both steady-state and dynamic response.

Your American Correspondents

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Massachusetts Institute of Technology

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* Our American Correspondents inform us that limited numbers of most of the Conference papers are available from Professor Stanley Backer, Room 3-336, Massachusetts Institute of Technology, 77 Mass. Avenue, Cambridge 39, Massachusetts, U.S.A.—EDITOR

CONTROL IN ACTION

Month by month—reports from the field

A water-level control system

Maintaining a constant head for a power station's condensers

by **J. L. LEONARD** M.Sc., Ph.D. *and* **H. EVENDEN,** *Bruce Peebles & Co. Ltd*

POWER STATIONS REQUIRE CONSIDERable quantities of water for their condenser units and ancillary equipment. Obvious sources are large rivers, but these may be subject to variations in flow, as, for example, when the river is tidal. Failure to supply water at a sensibly constant head can result in the shut-down of the generating plant, so the engineer may be faced with the problem of pumping water from a variable river into suction pits supplying the condenser units. In such a case some form of reliable and robust pump-control gear is needed.

A particular control system which has been applied to this problem is designed around a pump, devised by Vickers-Armstrongs Ltd, which operates from an ordinary a.c. induction motor running at a constant speed. The pump is an axial-flow device using impellers of a pitch which can be varied by a hydraulic ram. The flow of oil to the ram is controlled in accordance with the water level in the chamber supplying the condensers.

The system may well be unique: given the special axial-flow pump, it is simple and straightforward, and offers none of the difficulties met with variable-speed pump motors and their associated control gear.

Any system seeking to control large devices with inherent time lags, can rarely be designed precisely. Each separate installation presents the designer with special stability problems. In this particular system, stability is dependent on several factors, including the lengths of the culverts carrying the pumped water, the head of river water acting against the pumps, and the volume of water within the control loop at any given time.

Fig. 1 illustrates a typical arrangement which is now operating in a power station in South America. This

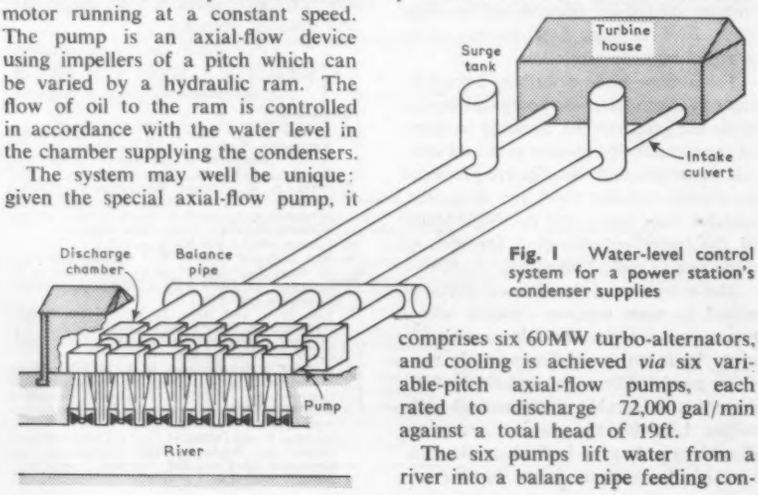


Fig. 1 Water-level control system for a power station's condenser supplies

comprises six 60MW turbo-alternators, and cooling is achieved *via* six variable-pitch axial-flow pumps, each rated to discharge 72,000 gal/min against a total head of 19ft.

The six pumps lift water from a river into a balance pipe feeding condensers in the turbine house *via* two supply culverts. The river is tidal and the control system varies the rate of pumping to maintain a sensibly constant head of water at the input to the condenser circulating pumps. The supply culverts contain surge tanks to buffer the effects of sudden pump changes or unusual river conditions. The number of pumps used at a time depends on conditions. Normally five might be used, with a sixth on stand-by, but in the event of maintenance work on a culvert, three pumps only would be used. To allow maximum flexibility, individual control of the pumps was therefore required.

The system was designed to the following specification: (1) The water level in the surge tanks is controlled to within ± 3in at two levels 2ft apart. This requirement caters for the failure of one of the pumps in the turbine house causing other pumps to demand greater amounts of water in order to supply the condensers. (2) Any loss of water-level information causes the maximum pumping condition. (3) In the event of arduous tidal conditions, which could cause the pump-motors to overload, there is a reduction of pump-pitch.

The axial-flow pump

The heart of the level-control system is the variable-pitch axial-flow pump. This is designed to suit any particular application, and Figs. 2 and 3 show typical pumps complete with their control systems. These are powered by a.c. motors developing 850hp

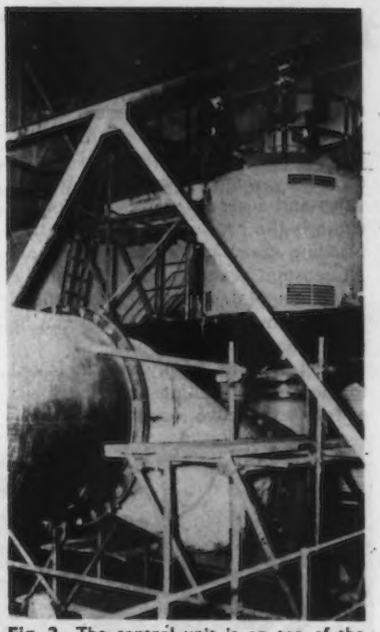


Fig. 2 The control unit is on top of the impeller-drive motor

from a 6·6kV, three-phase, 50 c/s supply.

Adjustment of pitch is achieved by axial movement of a shaft concentric with the pump axle. A cam action causes the pump blades to open and close, and the reaction against water pressure is partly carried by the cam arrangement and does not react directly on the driving shaft. The latter culminates in a hydraulic ram which supplies the power for pitch control. A thrust of 3500 lbf is required to initiate impeller action under the worst conditions, and the ram movement between maximum and minimum pitch is 4in. Normally, an oil pressure of 300 lbf/in² is used to drive the ram.

On–off control

A simple on–off control system was selected for positioning the pump impellers. The control signal actuates a solenoid valve which allows oil to be pumped to one side or other of the ram driving the impellers. When the correct ram-position is reached, the solenoid shuts, cutting off the oil flow and locking the ram.

Two methods of providing this on–off system were considered originally. In one, a signal derived from the water level was compared with a reference, and the pump impellers were increased or decreased in pitch according to whether or not the water-level signal was greater than the reference signal. Here, it was felt that there was a danger of the time-lags inherent in the pumping paths causing the pump to oscillate between full and zero pitch.

An alternative method in which the pitch of the impeller is made proportional to water level was therefore chosen. This second method was chosen solely with stability in mind; it is potentially less accurate than the first method since there can never be any one specified water-level datum which the system seeks to reach. Instead, the water level must fall before the pump increases its delivery of water. In practice, the level-change required to change the pump-pitch from zero to maximum is 6in.

The overall control system is shown in Fig. 4.

The water-level detectors housed in the supply culverts are of the displacement type. A partly submerged plunger loses or gains apparent weight as water rises or falls around it. This change causes a slight movement of an armature in a magnetic field, so unbalancing a valve-oscillator circuit which controls the mean current into an electromagnet pulling on the armature in opposition to the plunger. The current is adjusted in such a manner that the armature is held in an almost constant position, the current fluctuations being proportional to the apparent weight changes of the plunger and, thus, to the water level. The current from the detectors is fed to a control winding of a two-stage magnetic amplifier.

The first stage of the magnetic amplifier is linear and has three control windings; the second stage has an on–off push–pull characteristic and energizes one or other of two solenoids according to the sense and magnitude of the output from the first stage. The solenoids actuate a hydraulic valve which controls the oil-flow into a ram driving the impeller blades of the pump, the direction of ram-movement being dependent on which of the two solenoids is energized. When both solenoids are de-energized, oil-flow to the ram is blocked and the system locks. The ram is coupled to a pick-off element, a linear variometer, the output of which is rectified and fed to a second control winding in the first stage of the magnetic amplifier. The action is then as follows. The magnetic amplifier receives a signal proportional to water level. If the pump impellers are not at a pitch corresponding to this level, the output stage of the magnetic amplifier energizes the appropriate solenoid, allowing oil to flow into the ram and drive the impeller. The signal from the ram pick-off subtracts from the water-level signal in the first magnetic amplifier and, when the two signals are equal, the solenoid is de-energized and ram-movement stops.

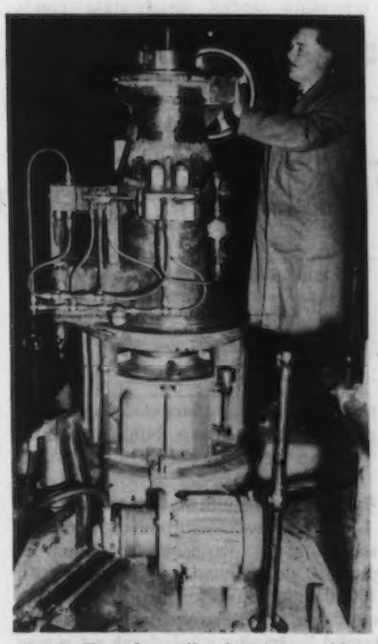


Fig. 3 Top of impeller-drive motor. Note hydraulic control gear

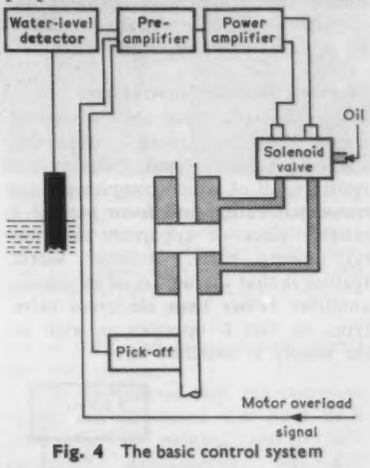


Fig. 4 The basic control system

Stability is obtained by the use of a dead zone in the magnetic amplifier characteristic. Thus, the solenoids are de-energized as equality of signal is approached rather than when it is reached. The ram is then allowed a short distance of travel in which to rest before the magnetic amplifier energizes the opposing solenoid. The dead space is equivalent to a water level of 0·5in.

The third winding on the input magnetic amplifier carries a signal derived from a current transformer in the supply to the pump motor. As the latter approaches full value, a

current flows in the third control winding which subtracts from the water-level signal and demands a smaller pump-pitch. This protection circuit is only active as full-load con-

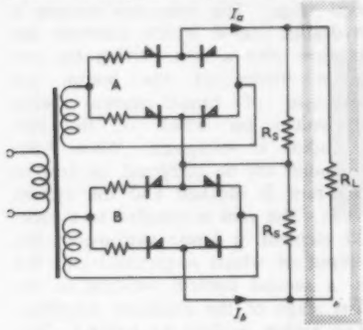


Fig. 5 Magnetic amplifier circuit

ditions are approached; normally the current-transformer signal is blocked by a biased diode arrangement.

Magnetic amplifier control unit

The complete control unit consists of transformers, magnetic amplifiers, silicon rectifiers and wire-wound resistors, all of which components are non-deteriorating and form part of a reliable piece of apparatus that has no moving parts. Another useful feature is that the unit is of magnetic-amplifier rather than electronic-valve type, so that it operates as soon as the supply is switched on.

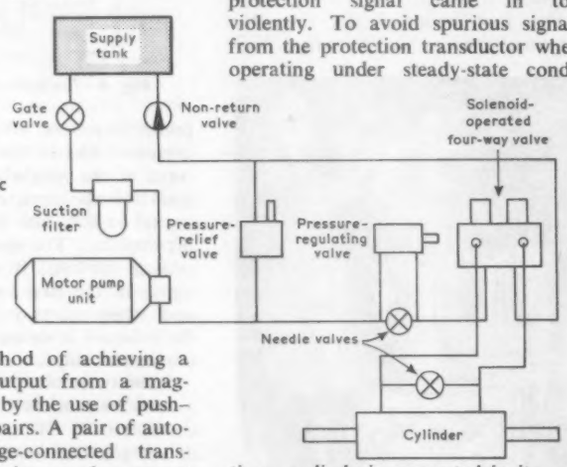


Fig. 6 Hydraulic circuit

The usual method of achieving a duo-directional output from a magnetic amplifier is by the use of push–pull transductor pairs. A pair of auto-self-excited bridge-connected transductors (Fig. 5) gives a d.c. output feeding into a resistive-series summing circuit. The output currents of the two transductors are applied to equal resistors R_s, which are series-connected so that the load-voltage is the difference of the resistor voltages. When the transductor currents, I_a and I_b, are equal, the output voltage is zero, but application of the control signal unbalances the transductor currents and results in a load voltage and current depending on the sense of the signal.

The load *RL* consists of two paralleled control windings of a further pair of auto-self-excited bridge-connected transductors, arranged to give a duo-directional output. Unlike the pre-amplifier, where each transductor was biased halfway up its transfer characteristic to give an output linearly proportional to the applied signal, the second pair of transductors is biased to have low standing currents with zero input. When a signal is applied, the output of one transductor rises while the other remains inactive. The dead zone is easily obtained by biasing both transductors further off.

Yet another auto-self-excited transductor is used to sense the overload current of the motor. This transductor is biased off so that very little output appears across its load resistor and a control winding of the pre-amplifier, until full motor-load current is approached. Then its output increases linearly with further increase in motor current.

The output current from this transductor is summed magnetically in the pre-amplifier in such a fashion as to assist the water-level signal and thus reduce the pitch of the impeller. The sensitivity of this protection transductor can be altered, as it was felt that the system would oscillate if the protection signal came in too violently. To avoid spurious signals from the protection transductor when operating under steady-state conditions, a diode is connected in its output to inhibit signals but to conduct when an overload occurs.

Auxiliary hydraulic equipment

The hydraulic equipment is shown schematically in Fig. 6. The oil pump, developing a pressure of 300lbf/in², draws oil from a supply tank *via* a filter. Protection is obtained by having a relief valve for bypassing the pump output to the supply tank in the event of excessive pressure rise.

As an on–off system of control is used, it is desirable to control the maximum speed of movement of the ram. It follows that the rate of oil-flow must be controlled, and this is achieved *via* a pressure-regulating valve and a needle valve. The former controls the pressure across the latter, bleeding excess oil to the supply tank. At constant pressure across the needle valve, the flow through it is defined precisely by its aperture which can be set to the required opening.

Oil from this supply system is fed to the ram controlling pump-pitch *via* a four-way valve operated by twin solenoids as described earlier. A by-pass needle valve across the ram allows it to be moved manually in the event of a failure of control equipment.

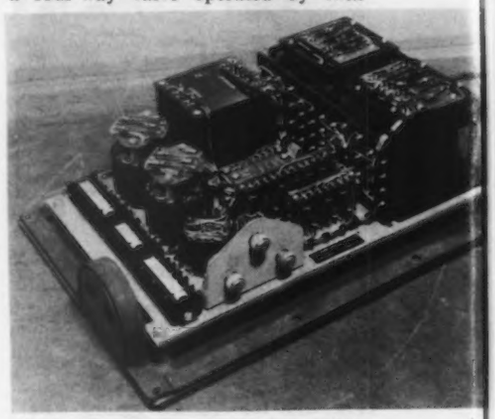


Fig. 7 The electronic control unit, with its magnetic amplifiers and associated components, bolts on to the body of the main pump

All the hydraulic components are standard items, and are assembled on to the body of the main pump.

Conclusion

Numerous applications other than that of power-station water supply are feasible, with only slight modification of the fundamental scheme. The most significant feature is the basic simplicity of the control system. Existing pump-control schemes use variable-speed motors to drive pumps and, in arduous conditions where these motors cannot use brush-gear, complex arrangements of rotating plant are used to supply an a.c. induction motor.

The water-level detectors apart, all components are of solid-state type and extremely robust.

Fig. 7 shows the electronic control unit containing the magnetic amplifiers and associated resistors and transformers.

Testing transistors automatically

Life-data acquisition at Texas Instruments

AUTOMATIC DATA-ACQUISITION EQUIPment now operating at Texas Instruments' semiconductor plant, Bedford, records the results of parameter measurements made on 2000 transistors undergoing extended life test. The transistors are housed in five temperature-controlled ovens—400 devices in each oven—and are operated at the maximum rated dissipation for the temperature (up to 200°C) within the ovens.

Although it is desirable that each of the 2000 devices should be scanned automatically, this was thought to be too costly, and so in this equipment each device is selected manually, the particular circuit being set up and the actual measuring and recording carried out by fully automatic means.

The input leads for the 400 devices in each oven terminate in forty separate modules housed in a double-bay distribution rack, there being five such racks in all. Each module carries a multi-way socket and an eleven-way rotary switch. An operator inserts a pistol-grip plug into the multi-way socket and selects the device required on the rotary switch. The multi-way plug has a flying lead which connects the device to the automatic measuring equipment; the plug also incorporates interlock wiring, a monitor lamp, and a trigger switch with which to start the automatic testing equipment.

When the plug is inserted and the first device selected, the monitor lamp will light if the data-handling equipment is in its 'start' condition, and operation of the trigger switch then starts the testing sequence. The parameter data of each device, together with the date, time and device number, are recorded on a punched card and also in tabulated form on a typewriter. The date is derived from a date switch, the time from a digital clock and the device number from a coding system within the distribution racks. This block of information is punched out by an I.B.M. punch, and typed by an Addo-x printing tabulator before any measurements are made. During this punching and typing operation, the device selected is still in its life-test dissipation condition.

Next, the device is connected into the first of its parameter-test configurations and a digital voltmeter is connected to the required test point. A delay of 100ms allows the device to settle into its new circuitry, and the digital voltmeter is given a 'digitize' pulse. When the digital voltmeter has completed its conversion, the digital measurement is read out into the card punch and the tabulator, the device being returned to the full dissipation condition. The transistor is then connected into the next test configuration, where it is allowed the same settling time, the digital voltmeter takes the next reading and data are punched and tabulated. The process is repeated until all parameters have been recorded, after which the card punch ejects the card, and the tabulator makes a carriage-return and line-shift. The monitor lamp on the pistol-grip plug then indicates that the data-handling equipment can accept a new set of data and the operator selects the next device.

Texas Instruments' transistor life-testing equipment. The data-acquisition equipment is in the foreground, and the distribution racks are on the left. The five temperature-controlled ovens, each of which houses 400 devices undergoing life test, are behind the racks.

It is understood that the complete system was designed and built in a little over six months, and is now operating satisfactorily. Microcell Electronics provided the automatic data-acquisition equipment, and Linvar Ltd the cabinets and wiring.

Induction heating at Vauxhall's

Among induction-heating equipment installed by Delapena & Son Ltd at Vauxhall Motors' Luton works, is a machine by Fritz Dusseldorf of Freiburg, W. Germany, known as an automatic horizontal shaft-hardening machine. Operating with little or no attention, this heat-treats components of the new Victor car's gear-box, such as small shafts and pins, on a continuous production basis. It can harden either the complete surface of a component, or selected zones only, and the limits of the hardened area, depth of hardening and degree of hardness, are reported to be accurately controlled and consistently maintained over long production runs.

The feed and traversing mechanism is shown in the illustration. This feeds components to the work station, passes them through the work coil (the r.f. heating inductor) and the water-quench ring, and then ejects them. Components for treatment are stacked on a sloping tray, the workpiece at the lower edge of the tray resting against a stop at the side of a pair of rollers. The latter are slightly inclined to the horizontal, and can be rotated in the same direction by a motor. There is a small clearance between the rollers, each of which is reduced in diameter over a short portion of its length to form a narrow neck. The gap formed by these necks accommodates the work coil and spray-quench ring. The lower end of the roller arrangement is aligned with a vee-section slideway, and at the upper end (right-hand end in illustration) a push-rod driven by a piston in a hydraulic cylinder is parallel to, and between, the rollers.

In a typical operating cycle, such as that for hardening the striking-fork rod in the illustration, the workpiece is lifted over the magazine stop by a feed-finger to roll into position between the rotating rollers. The traversing push-rod pushes the component through the work coil until the hardening zone is reached, when the r.f. power is switched on automa-

Work coil, quench-water ring and feeding and traversing mechanisms of the automatic horizontal shaft-hardening equipment at Vauxhall Motors

tically. The push-rod then 'dwells' for a short period to allow hardening temperature to be attained at the start of the zone, after which it traverses the workpiece at a predetermined rate through the work coil, r.f. power switching off automatically at the end of the hardening zone. On this particular component there is a single hardening zone, but there may be two or more zones for each of which a similar heating sequence occurs.

On emerging from the work coil, the workpiece passes through a continuous-spray quench ring. The push-rod is then withdrawn at a fast return speed, allowing the next workpiece to be fed on to the rollers, and the traversing stroke is repeated. Treated workpieces push the preceding components along the rollers and on to the vee-slide.

Among the controls provided for the setting up and regulation of a hardening program are the timing of the automatic feed, a variable rate of traverse for the workpiece, on/off switching of the r.f. power one or more times depending upon the number of zones to be heat-treated, and control of the cooling- and quench-water flows.

Computer-controlled oil distiller

On-line closed-loop control of a new 85,000 barrel/day oil-distillation unit at the Tulsa refinery of DX Sunray Oil Co., is now being exercised by a Thompson Ramo Wooldridge RW-300 computer. According to International Systems Control Ltd, the RW-300 provides continuous and automatic control by continually scanning 191 process instruments and adjusting thirty controller set-points to maintain optimum efficiency. Such variables as temperatures, pressures, flow rates and stream compositions are checked every ten minutes and their readings are compared with predetermined limits stored in the computer's memory. Using this instrument data and a mathematical model of the process, the computer controls the distillation unit directly by automatically adjusting the appropriate controller set-points. In addition to the RW-300, the control system includes an operator's console, analogue input equipment, and three automatic logging typewriters which provide a printed log of all process variables bi-hourly, daily and on demand.

B.R's anti-aircraft trip wire

Last year an aircraft overshot the runway at Southend Airport and blocked British Railway's Shenfield-to-Southend railway line near Rochford. In order to minimize the danger if this should occur again, B.R. have fitted a trip-wire operated alarm system. This consists of a tensioned wire carrying a 24V d.c. supply, breakage of which puts both the 'up' and 'down' signals to danger and causes an alarm bell to ring at Rochford station. The circuit cannot be restored once the trip wire has broken, even if both broken ends are earthed. Once the tripping circuit has been actuated, normal working can only be resumed after the wire has been repaired, or by the use of a special key.

A half-wave rectifier is connected in series with the trip-wire circuit in order to quench any spark which might occur at the break, and possibly ignite fuel from a damaged aircraft.

Wandsworth logs refuse-data

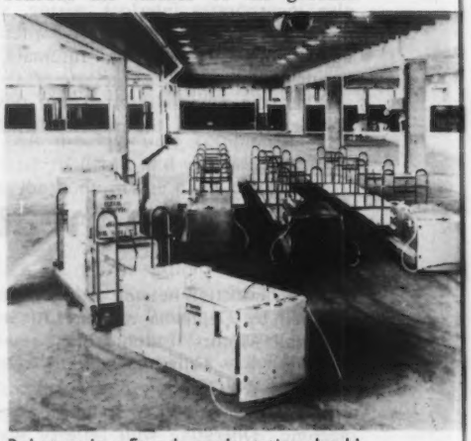
A digital weighing information system by Digital Engineering Co. has been installed by Wandsworth Borough Council, with the aim of improving refuse collection within the Borough. The installation, which has been approved by the Board of Trade, records and analyses details of vehicles emptying their loads—identifies the vehicle, the weight of refuse carried, times the weighing, etc. The data is automatically punched into tape and fed into a tape-to-card converter. The punched cards are then put through a tabulator to give a record of individual weighings, and subsequent analysis determines the sum to be paid according to the weight of refuse collected.

Each loaded vehicle is driven on to a weighbridge and halted, and the resulting angular position of the weighing scale's pointer is turned into digital form by a digitizing switch. This switch is operated by the decimal print-out mechanism of an Ashworth Ross Weighprinter indicator, and the digitized output is fed from the control console to a five-channel tape perforator. Operation of a printing button records the weight in decimal form on the Weighprinter ticket and the internal master record, and also incorporates it in the data being punched into paper tape.

A further development now under consideration is that operation of the weighing button should cause electrical impulses to be transmitted, *via* a rented Post Office line, to a central point where they would operate a page printer and tape perforator.

Robotugs at Paris goods station

Eight Robotug driver-less tractors by E.M.I. Electronics are now in use at a new goods station in Paris, which is operated by Danzas Transport in co-operation with the French National Railways. The installation is expected to handle 1000 tons of goods a day. The tugs are fitted with the usual guidance equipment which follows the magnetic field generated by a wire beneath the surface of the ground.



Robotugs in a French goods station should handle 1000 tons a day

This 'track' is divided into blocks, one Robotug at a time being allowed in a block. The Danzas system comprises twelve block cabinets each of which supplies seven blocks, and thus there are 84 sections of track.

Provision has been made for all the tugs to return automatically to a central control point.

NEWS ROUND-UP

from the world of control

PROFESSIONAL

Brit.I.R.E. to join B.C.A.C.?

The British Conference on Automation and Computation has been attacked occasionally on the grounds that it is not truly representative of the British engineering societies. The main grounds lie in the Brit.I.R.E.'s exclusion from the B.C.A.C., a subject discussed in a leading article in *Control* over two years ago (page 79, September 1959). Now it looks as if this unsatisfactory state of affairs may —given good will on all sides—be satisfactorily concluded. The reasons why the Brit.I.R.E. did not join the B.C.A.C. when the Conference was first formed are rather obscure. It appears that the B.C.A.C.—like Topsy —'just growed' at first, with the three senior institutions, Civils, Mechanicals and Electricals becoming members as of right. The Brit.I.R.E., on the other hand, was obliged to apply for membership. The subsequent negotiations were so lengthy (indeed, it was even rumoured that the application was blocked by one of the senior institutions), that the Brit.I.R.E. eventually withdrew in a huff.

Now the situation is rather different: the Brit.I.R.E. has its Royal Charter, and the I.E.E. is thought to be on the verge of approaching the junior institution with a view to collaboration in various unspecified fields.

The way would now appear to be open for the Brit.I.R.E. to become a full member of the B.C.A.C. However, there are still minor points of difference. For example, *Control* understands that the Brit.I.R.E. would be delighted to receive an invitation to join the Conference; some B.C.A.C. members, on the other hand, feel that the Brit.I.R.E. should now feel encouraged to join. If this means that the Brit.I.R.E. must apply for membership once again, rather than be invited to join, it could be that, secure with its Royal Charter, it may well 'play hard to get'.

Adaptive symposium

At the Brit.I.R.E.'s symposium on *Adaptive optimizing control*, held in London on 22 November, contributions were made by three speakers, all having both a theoretical and practical interest in adaptive control.

S. L. H. Clarke, of Elliott's, opened with an elementary explanation of single-variable extremum controllers, discriminating between 'peak-holding' and 'peak-seeking' systems. He went on to describe the principles of the Elliott Optimat three-variable optimizing controller. The application of Optimat to a Mobiloil distillation column at Coryton came up in discussion later, and Clarke admitted that no immediately useful results were achieved, but maintained that valuable experience and know-how had been acquired. It appears that noise and drift caused more trouble than had been anticipated, and another experiment is to be made elsewhere with modified equipment. Clarke concluded that applications of this kind were unlikely to succeed unless predictive (or feedforward) control were incorporated.

Clarke's point on predictive control was taken up by P. H. Hammond, of the N.P.L., quoting a biological analogy. Experiments at Cambridge on the adaptation of the human eye had showed that the focusing mechanism adjusted itself more rapidly to distance changes if feedforward information were given. Hammond then described work being done in the Autonomics Division of the N.P.L. on 'hill climbers' and other adaptive devices, illustrating his talk with slides and randomly selected cuttings from an N.P.L. film.

Professor J. H. Westcott of Imperial College, possibly the most adaptive control speaker in the business, gave the final address. After stating his belief that optimal control by computer on large plants would soon be economically justifiable, Westcott revived the slightly flagging audience with an amusing analogy between schoolboy-type laboratory distillation and the much-discussed distillation column. This was used to illustrate a multi-variable problem, and became the jumping-off point for a slightly abstract dissertation on the dynamic-programming approach. Though formidably academic in some respects, Westcott clearly accepted the inevitability of noise and other practical disturbances, in contrast to those theoreticians who regard such things as unfair.

The discussion which followed the meeting, showed that the Brit.I.R.E. is interested in adaptive systems, and that its members had some original comments to make. Clearly, interpretations of the words 'optimizing' and 'adaptive' are still varied. One speaker from the floor alleged that none of the contributors had said very much about either type of control, but it transpired that his troubles were largely linguistic. In all, the Brit.I.R.E. is to be congratulated on this symposium, which must be rather on the fringe of its normal field.

Ifac's new Council

The new Executive Council of the International Federation of Automatic Control has been elected by the national member organizations. Professor Ed. Gerecke (Zurich) is now President of Ifac; J. F. Coales (Cambridge) and Professor P. J. Nowacki (Warsaw) were elected Vice-presidents. The former President, Professor A. M. Letov (Moscow), now holds the office of Past President in the Executive Council. Professor J. C. Gille (Paris), Dr J. C. Lozier (Whippany, New Jersey, U.S.A.) and Academician Gr. Moisil (Bucharest) were elected Ordinary Members of the Executive Council.

Department of Automation?

'The sooner a Department of Automation is established in this country, the better. Industrial experience has always shown that unless somebody is given the responsibility for the development of a science or technology, progress very nearly marks time'. So said L. Landon Goodman in his address to the North West Middlesex Branch of the British Institute of Management on *The challenge of automation* last month. He was elaborating on a suggestion that he had recently made at the National British Institute

of Management Conference, and said he was conscious of a great deal of support for his idea in managerial, trade union and research association circles. Goodman went on to say that a Department of Automation would be organized on a national basis, representative of trade unions, management and the Government, to deal with the problems that automation might bring to industry and to speed up its introduction. The Department would act as an intelligence and information centre.

RESEARCH

Work at Imperial College

Automatic control systems, a short review of research in progress in the Electrical Engineering Department at Imperial College, has been received from Professor J. H. Westcott. Work is proceeding on the theory required for the integrated control systems for complex industrial processes. Variational and dynamic programming techniques are being used to give a method of computing a sequence of control actions, a digital computer simulating both system and controller. At a later stage, the problems of associating computer-like devices with industrial processes will be considered. Stochastic theory is being used to describe controlled plant in which system parameters vary randomly.

Westcott himself is working on the parameter estimation problem—finding the most appropriate values of the parameters of a model to represent dynamically the physical connexion between recorded inputs and outputs of a system, and estimating the statistical parameters governing the input and output signals themselves. This work has implications for adaptive control. D.D.A. techniques are being applied by P. F. Blackman to the problem of devising a small and simple computer for evaluating complex frequency functions relevant to control systems. D. Q. Mayne is concerned with time series analysis.

The efficient utilization of the available data in self-optimizing feedback systems is to be studied by J. M. Howl, approximation methods in adaptive control are being investigated by J. J. Florentin, and optimization techniques for dynamic systems by J. D. Pearson.

Work by M. J. McCann is concerned with extending the variational methods of determining optimal control policies, and S. M. Lyle is using a digital computer to investigate probing techniques applicable to a two-control adaptive system operating a process whose response surface has many peaks.

The tracking characteristics of a human operator are being investigated by G. W. Lange, and this work has suggested a study of random sampling systems by D. Bryson-Haynes.

W. R. Atkins is working on an optimal design of adaptive network for use in radar signalling systems, and J. M. C. Clark on dynamic programming applied to the calculation of optimal trajectories and orbits.

The basic elements of adaptive control theory are being investigated by A. Straszak.

In the Instrumentation Laboratory (B.McA. Sayers) training at post-graduate level is proceeding on nuclear reactor instrumentation, and the application of engineering in medicine and biology, to give but two examples. Hybrid computers (analogue computation using digital methods) with adaptive features are being studied by R. L'Archeveque. Studies of the human brain function are concerned with self-organizing analogues (R. G. Pither), and adaptive activity (F. E. Toole).

In the Mathematical Machines Laboratory (J. R. Barker), which exists primarily to assist engineering students to apply their mathematics to physical situations, theoretical studies of electrical and mechanical vibrations are proceeding.

DATA PROCESSING

Univac research

The new Univac Engineering Centre of Sperry Rand Corp., which opened near Philadelphia in October, is reported to be carrying out much basic and advanced research. Techniques are being developed in which fluids will be used as amplifiers and in digital logical devices, and magnetic recording developments have resulted in pulse densities and tape speeds of 100 kc/s, and nine channels. Larger memory capacities and smaller memory devices are resulting from the high pulse densities on both drums and tape permitted by new methods of plating, and mass storage devices—drums, disk files, etc.—having between four and ten times the capacity and speed of present devices are foreseen. Developments in circuitry, using advanced components such as parametrons, tunnel diodes and very-high speed transistors, promise computer access speeds some twenty times higher than at present. Other work at the Centre is concerned with thin-film memories, programming—e.g. the 'Math-Matic' mathematical language, magnetic materials, single crystals, oxides, magneto resistance, and pneumatic devices.

STEEL

R.T.B.'s Spencer Works

The Spencer Works, Newport, of Richard, Thomas and Baldwin, the largest steel-works in Europe and possibly the most highly automated in the world, is expected to go into operation in the spring. So vast is the project, and so secretive are R.T.B. about it, that it is impossible to describe the control side of the works in any detail.

However, it is known that the works will be fully integrated with the aid of a high degree of automatic data processing. The main digital computer for one particular process is believed to be a machine by U.S. General Electric, although this has never been confirmed.

A recent statement from Elliott-Automation (made in agreement with R.T.B.), however, does give a few, rather vague, details. To quote from the statement: 'Spencer Works represents a major advance in that it combines the localized controls into an integrated system while retaining the essential flexibility of the individual sections. The control system receives a constant flow of demands for a variety of end products in varying quantities, qualities and delivery schedules and converts them into instructions. These instructions are broken down and refined by computers in stages in such a way that at each level they can be acted upon. These control instructions are complemented by technical instructions at appropriate levels so that the entire plant operates at its optimum efficiency. This flow of control information in a downward direction is then paralleled by a return flow of information which is signalled at all levels in the process, reporting what has actually happened at each stage. This information is assembled and assimilated by the computers and compared with the original instructions given. This enables each level of control to modify its instructions in the light of actual performance.'

It is understood that a number of Elliott 609 computing systems are being incorporated in the scheme, alongside the U.S.G.E. computer.

Apart from this very general information, little or nothing has been released, although a few details on specific subjects have been published. Bruce Peebles are providing an electronic control system for overhead magnetic conveyors on the cut-up

lines; Brookhirst Igranic are providing automatic wagon-handling controls; Craven Electronics are installing seventeen weighers for belt conveyors together with data-transmission equipment; and Honeywell Controls are providing temperature, flow and oxygen analysing equipment for reheating and heat-treatment furnaces, together with instrumentation for other equipment.

MARINE

Controlling *Ashanti*

The Tribal class frigate H.M.S. *Ashanti* is the first ship of the Royal Navy to have steam-turbine propulsion machinery, together with a 7500hp gas turbine which may either 'boost' the conventional steam-turbine drive or, if need be, act as the main drive. *Control* attended *Ashanti*'s commissioning ceremony in Yarrow's yard, Glasgow, and was much impressed by the immaculately clean engine room and 'below-decks' machinery.

The gas turbine is geared to the same propeller shaft as the more conventional steam turbine and allows the vessel to get under way in a matter of minutes, thus overcoming the delay inherent in operating a steam turbine from cold. The gas turbine may also be operated in parallel with the steam turbine if high-speed cruising is necesary.

This dual-power arrangement necessitates control of some complexity. Both turbines are operated from a control console remote from the engine room, where a permanent watch need not be kept, all information regarding pressures, temperatures, shaft speeds and so forth being displayed in the air-conditioned control room. Automatics are used extensively: for example, the gas turbine is started manually but takes up the load automatically as soon as it reaches shaft-speed.

Ashanti is particularly interesting in that it may well presage the full control of a vessel from her bridge.

The propulsion machinery was developed jointly by the Admiralty, the Yarrow Admiralty Research Department of Yarrow & Co. Ltd, and A.E.I. Ltd, who built both turbines.

PROJECTS

U.S. computer-control sales

According to International System Control Ltd, the British G.E.C.–T.R.W. concern, Thompson Ramo Wooldridge Inc, have sold three digital computer-control systems recently, two to the Tennessee Valley Authority, and one to the Celanese Corp. of America.

Power station control

The two computers for the T.V.A. will each control a 650MW installation in the Paradise Power Station at Drakesboro, Kentucky. The first unit is scheduled to begin operation in the autumn of next year and the second in mid-1963. The system will automatically control the turbine generators, and sequence-monitor the steam generators. It will sequence cold start, hot re-start, shut-down or emergency shut-down of the units and, in addition, carry out sensor scanning and alarm monitoring, data logging, trend recording, and perform the necessary calculations.

Chemical process control

The digital computer system for the Celanese Corp. is to control two of the four primary oxidation units at a plant at Bishop, Texas. At present production at the Bishop plant is approximately 400,000 tons a year, and computer control is expected to result in increased throughput and yield, by closer control of such factors as chemical reactor temperature, and richness of feedstock. The computer will exercise closed-loop control over the non-catalytic vapour-phase process that converts propanes and butanes to formaldehyde, acetaldehyde, methanol, ethanol, acetic acid, acetone, and other chemicals. The system will sense about 150 process variables and will control the 24 process variables which affect production levels. It will automatically modify coefficients of the mathematical model stored in its own memory as the characteristics of the plant change. In addition the machine will print out hourly and daily logs of operating data.

EXHIBITIONS

The Phys. Soc.

The 46th Exhibition of Scientific Instruments and Apparatus—still better know as the 'Phys. Soc.' in spite of the fact that nowadays it is presented by the Institute of Physics and The Physical Society—takes place at the Royal Horticultural Society's Halls, Westminster, London (just south of Victoria Street) from Monday 15 to Friday 19, January 1962.

As ever, the show provides a good cross-section of the British instrument world, and although many of the exhibits have a flavour more of the laboratory than the shop floor, this after all was always the intention. Indeed the Phys. Soc. is often criticized on the grounds that it has become too commercial in recent years.

There are 130-odd exhibitors, a good number in a year which will include the much more down-to-earth I.E.A. Exhibition (28 May–2 June 1962), and there is little doubt that it will be as busy and crowded an event as at any time in the past.

There is no doubt that the Phys. Soc. does a worthwhile job and is deserving of every support. Attendance is strongly recommended.

NEWS BRIEFS

The application of automatic control techniques to machine tools: the B.C.A.C. has invited the I.Mech.E. to organize a meeting to discuss this subject during the Instruments, Electronics and Automation Exhibition, Olympia, London, 28 May–2 June, 1962.

Digital Measurements Ltd, 25 Salisbury Grove, Mytchett, Surrey, has been formed to produce data loggers and processers and electronic instrumentation.

Brush Crystal Co is now controlled by Clevite Corp., U.S.A.

de Havilland Pottermeters: seven 18 in flowmeters are to monitor the oil-flow through the 479-mile South European pipeline.

National-Elliott 803 computer has been ordered by the P.O. for its satellite system radio station on the Lizard, Cornwall.

Société Européenne pour le Traitement de l'Information, (automation, data processing, etc.) has been formed by Packard Bell Electronics Corp., U.S.A., and Cie des Comteurs, France.

Computer Services (Birmingham) Ltd are establishing a computer service bureau in Birmingham early in 1962. A Remington Rand Univac 'Solid State 80' computer will be installed.

Satellite-data recorders: three magnetic tape recorders have been ordered from Solartron by D.S.I.R. for recording data telemetered from instrumentation satellites. One is for use in the Falkland Isles, one in Singapore, and the third will be used with the Minitrack installation at the Radio Research Station, Winkfield.

Hellerman Deutsch Ltd, Gatwick Road, Crawley, Sussex, has been formed by Bowthorpe Holdings Ltd (51%) and the Deutsch Co., California, U.S.A., to manufacture Deutsch and Hellerman connectors and other products.

International Journal of Production Research, a new quarterly, the first issue of which is dated November 1961, is aimed at academics and research and development workers. The Hon. Editor is Professor N. A. Dudley whose 'Viewpoint' *People and processes* appeared in *Control* in March 1961.

COOMBS
air pilot

NEWNHAM
sea gunner

WHITE
new Texan

KENDALL
new firm

PEOPLE IN CONTROL

by Staffman

I see that Professor **T. Kilburn** and Dr **D. B. G. Edwards** of Manchester University have been lecturing on the Ferranti Atlas computer to Russian audiences at the Institute of Precise Mechanics and Computing Technique, Moscow. Apparently a great deal of interest was shown: indeed, I gather that the Russians would like an Atlas, but are unable to buy one because of a British government trade embargo. According to Ferranti, the Russians believe in separate machines for scientific and data-processing work, and are working hard on the development of faster storage and other components in order to obtain powerful machines of relatively simple logical design.

L. F. E. Coombs, until recently Technical Secretary of the British Air Line Pilot's Association, has joined the Technical Sales Department of Smiths Aviation Division where he will, I gather, be concerned with marketing engine instrumentation and equipment. An ex-R.A.F. man, Coombs was in the aircraft industry engaged on design and development for Handley Page and Delaney Gallay. I understand that he played a leading part in establishing requirements for instrument and control layouts for civil aircraft.

A naval gunnery officer, Captain **I. F. M. Newnham**, has been appointed Manager of Short Brothers and Harland's Precision Engineering Division at Castlereagh, Belfast. The main activity of this Short Division is the design and development of guided weapons, including the naval Seacat surface-to-air missile. Another naval gunnery officer, Rear Admiral **J. Y. Thompson**, has joined Elliott Brothers 'to assume responsibilities in connexion with the company's work for the Royal Navy'. Elliott's have supplied the navy with navigational and gunnery control equipment for very many years.

Three new appointments within English Electric's Control Gear Division at Kidsgrove, appear to have been made in order to streamline their research and development program for multi-motor control centres, variable-speed drives, static switching and control gear for machine-tool drives and other industrial equipment. **F. E. Waspe**, now Chief Development Engineer, is responsible for multi-motor control centres. An ex-G.E.C. apprentice, he joined English Electric, Stafford, in 1948, and has been Industrial Control Engineer at the Bradford Works. **G. H. Gunnell**, now Chief Control Engineer, is responsible for all the control engineering for everything from multi-motor centres to machine-tool drives. He joined E.E. as an apprentice in 1940, and has done work on magnetic slip couplings, power station auxiliary drives, and such test plant as R.A.E.'s high-speed wind tunnel. **E. J. Pepper**, now Chief Design Engineer, is responsible for the component circuitry for industrial drives and controls where static equipment such as magnetic amplifiers and semiconductors are employed. An E.E. engineer apprentice in 1945, he moved from Stafford to Kidsgrove in 1955, and has been responsible for magnetic amplifiers for industrial controls.

Plessey's subsidiary, Ketay Ltd, have a new Chief Engineer, **K. J. Coleman**, who joins Ketay from Babcock and Wilcox where he was Head of Control and Instrumentation of the Atomic Energy Department. Earlier he was with de Havilland Propellers as Senior Development Engineer and Head of the Alternator Development Department.

I see that **Jack White**, who was a member of the Commercial Section of Mullard's Semiconductor Division, has moved to Texas Instruments as Sales Administration Manager. In the same vein, **J. T. Kendall**, who was Texas's Manager of the Transistor Department, has become Managing Director of Microwave and Semiconductor Developments Ltd, a new concern formed to exploit the microwave applications of semiconductor devices. All three of the new company's executive directors were at Texas Instruments with Kendall, **R. G. Hibberd** (Chief Engineer), **J. J. Tither** (Sales Manager), and **M. S. Alderson** (Technical Manager). Before going to Texas, Kendall was in charge of Plessey's research into semiconductors.

AUTHORS IN CONTROL

A. J. Maddock (*Detecting elements and how to classify them*, page 84) graduated from Liverpool University and then spent several years in the research departments of British Thomson-Houston and of Thermal Syndicate Ltd. He joined the radio division of Standard Telephones and Cables and was with that company for eleven years, being responsible for many of the large radio-transmitting stations in this country and abroad; he was also concerned with radio-frequency heating equipment. Since 1946 he has been with the British Scientific Instrument Research Association, first as Head of the Electronics and Electrical Departments and later as Deputy Director. Dr Maddock is a Vice-chairman of the I.E.E.'s Measurement and Control Section, and has been Chairman of the London and Home Counties Branch of the Institute of Physics, a member of the Institute's Board, and Secretary of the Electronics Group.

G. P. Tonkin (*Digital inclinometer for automatic incidence setting*, page 88) took his B.Sc. (Physics) at Bristol University in 1944, and became a Radio-Officer in the R.N.V.R. In 1947 he joined Geophysical Surveys and, two years later, his present company, Bristol Aircraft Ltd. There he was concerned with g.w. electronics until 1954, wind-tunnel instrumentation until 1957, and was Head of Instrumentation Laboratories until 1960. Tonkin is now an aircraft Chief Project Engineer.

J. K. Chuchla (*Industrial timing problems*, page 92) received part of his technical education at the South West Essex Technical College after the war, and then worked with a number of firms in the electrical control field, including Londex. He joined the Electrical Remote Control Co. as Chief Designer in 1951, and was responsible for the company's original range of timing equip-

ment. Chuchla became Managing Director of Electrical Remote Control—his present position—in 1955.

J. W. Head (*Network Theory at Cranfield*, page 96) has been mathematical consultant to the B.B.C. Research Department since 1950. Born in 1912, he was educated at Marlborough and Trinity College, Cambridge. At first he taught mathematics at Cranford School and later at Malvern College. Subsequently he worked in the Vibration Department of de Havilland's, at T.R.E., Malvern, and as editor of the *Wireless Engineer Abstracts* at the N.P.L., Teddington.

B. L. Deekshatulu (*A slope method of approximation to the describing function*, page 99) received a B.Sc. (Engg.) degree in electrical engineering from Banaras Hindu University in 1958, and a Master of Engineering Degree with Distinction from the Indian Institute of Science, Bangalore, in 1960. His practical training was with the Calcutta Tramways Co. and the Tata Hydro Electric Power Supply Co., Bombay. Last year he was awarded a research Fellowship of the University Grants Commission, India, and since then has been at the Indian Institute of Science, Bangalore, working on non-linear control systems.

S. Demczynski (*Production control and machine loading in a jobbing shop*, page 102). See page 128, October 1961.

G. F. Brockett (co-author with W. J. L. Kennedy—below—of *Effects of adjacent piping arrangements on control valve characteristics*, page 105) graduated from Iowa State College with a B.S. degree in mechanical engineering in 1935. He then joined the Engineering Department of the Fisher Governor Co. of Marshalltown, Iowa, as a design and research engineer, becoming Assistant Chief Engineer in 1942 and Chief Engineer in 1945. In 1951 he transferred to the Sales Department as Chief Sales Engineer, and becames Sales Manager—his present position—in 1958. Brockett has been responsible for the development of many Fisher products including the displacement Level-trol. He is the author of numerous articles on control valves and actuators, and is well-known in the U.S.A. as a technical lecturer. He has been a member of the A.S.M.E. for many years, and a member of the Instrument Society of America since its inception.

W. J. L. Kennedy. (This American author's technical biography had not been received when *Control* went to press.)

DEEKSHATULU

TONKIN

DAVEY

MADDOCK

HEAD

PUN

MITTER

EVENDEN

LEONARD

A. W. Davey (*Brightness control for neon lighting*, page 111) was at Vickers-Armstrongs (Aircraft) from 1942–50, including his five-year apprenticeship. He then joined the Plessey subsidiary, Cottage Laboratories Ltd, where he was engaged on classified work for the government. He joined the G.E.C. Electronics Division (now G.E.C. Electronics Ltd) in 1960, and is at present in charge of the silicon controlled rectifier application group. He is engaged in developing a wide variety of static inverters, dimming equipment, motor control units, etc.

P. G. Morgan (*Novel method of vibration generation*, page 112). See page 128. October 1961.

Lucas Pun (co-author with Sanjoy Mitter—below—of *Control on the Continent*, page 114) is of Chinese origin, Portuguese citizenship, and has had a French education since the middle school. After getting B.Sc. and B.E.E. degrees from the University Aurora of Shanghai, he continued his studies at the Ecole Supérieure d'Electricité, Paris, from 1949 to 1951. After obtaining the degree of Ingénieur-Docteur from the University of Grenoble in 1954, he worked for two years in Paris. Since 1956 he has been with the Battelle Memorial Institute, International Division, at Geneva, as a research engineer. He has worked on many projects concerned with automatic controls and simulations, and at present is mainly concerned with process computer controls. He was honoured by the Société Francaise des Electriciens in 1955, and is a Swiss representative member of the Theory Committee of Ifac.

Sanjoy Mitter was born in India and educated at the University of Calcutta, and the Imperial College of Science and Technology, University of London, graduating in 1957. After graduation he worked in the Power Systems Communications Department of Brown Boveri, Baden, Switzerland, where he was concerned with the development of transistorized digital telemetering and tele-control equipment. Since March 1951, he has been a research engineer with Battelle Memorial Institute, International Division, Geneva. He is at present working in the field of computer control.

J. L. Leonard (co-author with H. J. Evenden—below—of *A water-level control system*, page 118) was educated at Manchester Grammar School and the University of Manchester. He graduated in 1953 with a B.Sc. in electrical engineering, and obtained his Ph.D. following research work on non-linear servo-mechanisms. He joined Ferranti, Withenshawe, and worked in the Simulator Section on the analogue computation of the Bloodhound missile. In 1958 he joined Bruce Peebles where he is now in charge of Background Development Work in the Electronics Division.

H. J. Evenden served an electrical engineering apprenticeship with J. Stone & Co., London, in 1954. His studies of electrical engineering at South East London Technical College were interrupted by service with the R.E.M.E., and his technical education was continued at Watford Technical College. In 1954 he joined Rotax and was engaged on the development of magnetic amplifiers in aircraft generating systems. He left Rotax in 1958 to join the Electronics Division of Bruce Peebles, Edinburgh, as a Senior Development Engineer. At present he is engaged on designing and developing magnetic-amplifier systems for industrial control.

New for the user

A monthly review of instruments, components, equipment and machinery for automation

For further information, circle the appropriate number on the reply card facing page 162

FLOW RECORDER

electrically- or spring-driven chart

A.E.I.'s model 202 flow recorder incorporates the Barton/A.E.I. differential pressure unit, which uses stainless steel bellows, and has a forged carbon-steel or stainless-steel housing. The chart drive can be electrically or spring operated, and standard charts can be supplied to cover periods of 1, 12, or 24h, or 7d; others are available to order, and a lever gear-change can be fitted if required. A differential pen is normally fitted, but a static-pressure pen, actuated by a stainless-steel pressure helix, with static-pressure ranges up to 10,000 lbf/in², is also available.

For more information write to: A.E.I. Ltd, Information Dept, Crown Hse, Aldwych, London, W.C.2, *mentioning Control. Or on reply card, circle* **No 524.**

ULTRASONIC-BEAM DETECTOR

transistorized

A unit by Tyer, using an ultrasonic beam at about 45kc/s, may be used in many applications where a photocell and light beam might be hampered by smoke, fog, or mist. Maximum length of beam is about 25ft, and provision is made to eliminate spurious operation of the detector by random noise from sources such as jingling keys or money. The equipment will operate from either 12V d.c. or 200–250V a.c. mains.

For more information write to: Tyer & Co. Ltd, Perram Wks, Merrow Siding, Guildford, Surrey, *mentioning Control. Or on reply card, circle* **No 519.**

DIGITAL VOLTMETER

automatic ranging

An instrument by Electronic Associates, the series 5001, provides automatic range- and polarity-selection on four ranges from ±1·1999 to ±1199·9V. An average of 200 readings/s may be achieved (excluding sign and range change), with a maximum error claimed to be ±0·01% full scale ±1 digit. A switch on the front panel selects either maximum input-impedance of 500MΩ on the low ranges, or a constant 10MΩ on all ranges.

Facilities include binary-coded decimal and decimal electrical outputs, with output buffer-storage, remote control of range selection, and remote conversion command. Indication is on an in-line projection display visible at up to 50ft from a wide viewing angle.

For more information write to: Electronic Associates Ltd, Victoria Rd, Burgess Hill, Sussex, *mentioning Control. Or on reply card, circle* **No 529.**

ELECTRONIC COUNTER

solid-state circuitry

The T.C.1.A counter, by Advance Components, has a frequency range from 1 c/s to 1 Mc/s, and will measure time from 3μs to 2777h; it also generates timing pulses from 10^{-1} to 10^{6} pulses/s, in decade steps, from a 300Ω source. The internal time-standard is thermally compensated to a 4 Mc/s A.T.E. crystal oscillator, divided down to 1 Mc/s; accuracy is given as ±1 parts/10^{6} from 10 to 30°C, and ±5 parts/10^{6} from 0 to 40°C.

Indication is on a six-digit in-line projection display, with a display time from 1 to 5s, or 'hold'. An output for an external recorder is provided, giving a staircase wave-form voltage for each digit in nine steps between −0·75 and −3·0V; source impedance is 2·5kΩ. Weighing 28 pounds, the unit requires a 40 to 100 c/s supply, at 85 to 140V or 190 to 250V.

Output for recorder

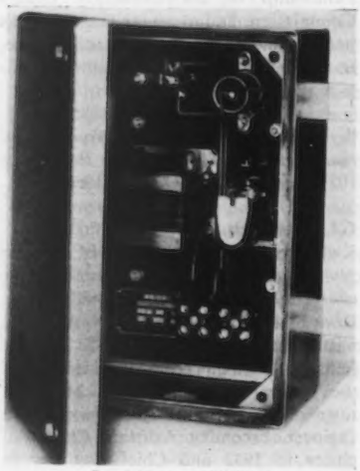
For more information write to: Advance Components Ltd, Roebuck Rd, Hainault, Ilford, Essex, *mentioning Control. Or on reply card, circle* **No 507.**

A.C. LOAD DETECTORS

withstand large currents

Units by Londex are for use in a.c. circuits which are subject to large current fluctuations, but where very small loads must be detected. The equipment consists of a saturable choke and a sensitive relay operated by voltage drop across the choke; a relatively small alternating current will provide a sufficient p.d. across the choke to operate the relay, but this p.d. will not increase materially when the load current rises. (Maximum p.d. is about 7V at full-load current.)

Two 25A continuously-rated models are the KR/CH and the SSR/CH, requiring 0·3 and 0·2A respectively to operate the relay. Two 50A continuously-rated models with the same type numbers operate at 0·5 and 0·3A respectively. The relay contacts may be normally open, normally closed, or change-over, and a typical rating is 3A, 250V a.c.



Sensitive to small loads

For more information write to: Londex Ltd, Anerley Wks, 207 Anerley Rd, London, S.E.20, *mentioning Control. Or on reply card, circle* **No 526.**

PRECISION ELECTROMETER

sensitive, stable

Wayne Kerr's M.141 electrometer has five direct-voltage ranges from 1mV to 10V, full scale, and (using three standard resistors) current ranges from 10^{-15} to 10^{-6}A, full scale. Input resistance is

greater than 10^{10}MΩ, and input capacitance is about 1pF, with a maximum charge sensitivity of 3×10^{-15} Coulomb. A feature of this instrument is a decade switch which precedes the meter indication; when the order of the quantity to be measured is known, the first digit of the reading can be transferred to the decade control and the meter will then indicate the second and subsequent digits. This is claimed to give a measurement accuracy of 0·1% of full scale on all ranges.

The circuit operates on the dynamic capacitor principle, and has an internal Weston cell which is automatically brought into circuit for calibration checks. The unit will work from 115 or 230V a.c. mains supplies.

For more information write to: The Wayne Kerr Laboratories Ltd, 44 Coombe Rd, New Malden, Surrey, *mentioning Control. Or on reply card, circle* **No 503.**

COMPRESSED-AIR FILTER

automatic draining

Doulton's air-line filter incorporates an automatic draining device which operates when the accumulation of liquid in the sump exceeds a certain level. This lifts a float which opens a small pilot-valve, admitting compressed air to a pilot-chamber and thereby actuating an oil-resistant diaphragm which opens the main scavenger valve. As the float drops, and closes the pilot valve, the main scavenger valve remains open for a period determined by an atmospheric bleed in the pilot chamber, so allowing complete drainage of the sump. Provision is also made for control of the amount of oil-mist introduced into the system.

For more information write to: Doulton Industrial Porcelains Ltd, Wilnecote, Tamworth, Staffs, *mentioning Control. Or on reply card, circle* **No 535.**

AUTOMATIC WAREHOUSING

electronically-controlled system

A joint venture by A.W.A. and Blackburn, a prototype automatic warehousing system, is now available for inspection. It consists of overhead-line gravity-feed storage bins, from which goods are fed on to a conveyor belt for transmission to a packing area. Up to five items can be released on to the conveyor each second, the gate of each bin being operated by a relay controlled from a central console.

Selection of items for a particular order may be made by manual switching or punched cards, and the system may be operated in three ways: manual—items selected by switch and delivered by operating a discharge button; semi-automatic—single cards read and processed individually; automatic—auto-controlled card reading, where cards are fed automatically to the reader until all orders are fully processed. Automatic 'out-of-stock' indication is provided, and an invoice stating price, sub-totals, and final total is automatically prepared as items are dispensed from the bins.

For more information write to: Hawker Siddeley Aviation, 32 Duke St, St James's, London, S.W.1, *mentioning Control. Or on reply card, circle* **No 536.**

VOLT- AND OHM-METER

five-digit display

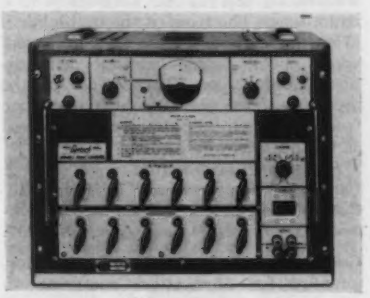
Ferranti's D201 digital meter has a voltage range from 0·1mV to 1000V d.c., and a resistance range from 0·01Ω to 1299·8kΩ. Ranging is automatic for all inputs except the most sensitive in each instance, which is selected by a 'divide by ten' switch. Input impedance on all voltage ranges is 4·44MΩ, but this can be increased to 10MΩ if necessary. Print-out facilities are available, and a parallel output may be fed to a suitable adaptor from the read-out sockets. After slight modifications the instrument will also measure current from 1·9999μA full scale to 1·9999mA full scale.

For more information write to: Ferranti Ltd, Ferry Rd, Edinburgh, 5, *mentioning Control. Or on reply card, circle* **No 512.**

VARIABLE PHASE STANDARD

three frequency ranges

The Gertsch (U.S.A.) VPS-1, now available from Wayne Kerr, has three adjustable frequency ranges covering 150 to 3000 c/s. Two voltages are generated, one a constant 50V r.m.s. reference phase, the other a variable phase which may be displaced up to 360° from the reference phase in increments of 1′. The latter has a maximum amplitude of 50V r.m.s., but



Self contained

can be attenuated by 50mV steps. The instrument is self-contained, and may be supplied either in a case or for rack mounting.

For more information write to: Wayne Kerr Laboratories Ltd, 44 Coombe Rd, New Malden, Surrey, *mentioning Control. Or on reply card, circle* **No 530.**

HIGH-SPEED RECORDER

direct writing

First of a range of direct-reading recorders by Devices Sales, the R.1 uses transistors in its amplifier and control circuits, and may be driven either from a.c. mains or a 12V accumulator. The moving-coil galvanometer is robust and completely sealed against ingress of dust, and a choice of two writing-systems is available: hot-stylus writing in rectilinear co-ordinates on heat sensitive paper, or inked-pen writing in curvilinear co-ordinates on untreated paper; the systems can easily be interchanged.

Any of six preset paper-speeds may be instantaneously selected by two lever-switches, the speed of the paper being governed by a servo-amplifier which continuously corrects the output torque of the d.c. motor drive to give a final drive-

Six paper speeds

speed accuracy of better than 2%. The recorder is claimed to write linearly over a 5cm pen-excursion, and the frequency response of the pen is given as 3dB down at 65 c/s.

For more information write to: Devices Sales Ltd, 13–15 Broadwater Rd, Welwyn Garden City, Herts, *mentioning Control. Or on reply card, circle* **No 514.**

D.C. AMPLIFIER

very small signal inputs

The A3 amplifier, made by Fenlow, is intended for use with very small inputs from strain-gauges and thermocouples, the d.c. gain being greater than 2×10^5. The band-width is 1 kc/s, and noise (referred to the input) is 5μV; input impedance is approximately 2kΩ. After initial warming-up, drift (referred to input) is less than 5μV.

Power supplies required are +15V and −15V; the negative supply takes 300mA initially, dropping to 80mA when the temperature-controlled block reaches 60°C; the positive supply draws 80mA. Output is ±9V into 1kΩ.

For more information write to: Fenlow Electronics Ltd, Springfield Lane, Weybridge, Surrey, *mentioning Control. Or on reply card, circle* **No 538.**

WATER-IN-FUEL METER

continuous indication

The B.P. Aquascan, manufactured by Thermal Control, continuously measures the undissolved-water content of aviation turbine fuel during fuelling. It works by optical comparison, based on the fact that undissolved water makes the fuel slightly hazy, and the opacity of the haze is proportional to the undissolved-water content. A dial indicator is directly calibrated in parts of undissolved water

New for the user

per million parts of fuel. Should the content exceed the recognized permitted maximum an automatic shut-down device stops the flow of fuel.

For more information write to: Thermal Control Co. Ltd, 138 Old Shoreham Rd, Hove, Sussex, *mentioning Control. Or on reply card, circle* **No 541.**

OPTICAL SHAFT-ENCODER

sine output-function

Shortly to be available from Armstrong Whitworth is the Avro 3in optical shaft-encoder. The output function follows the sine law, but two reading-heads may be fitted so that an output proportional to the cosine law can also be made available.

It is claimed that the ten tracks give a resolution of 1 part in 2^{10}, and accuracy is given as 0·001 radians. Maximum read-out speed is 100 rev/min. Residual torque and intertia are 0·139 ozf in and 0·3 oz in^2 respectively. Output, when on, is 6V at 5 kc/s into 3·3kΩ; ambient temperature range is 0° to 30°C.

For more information write to: Armstrong Whitworth Equipment, Hucclecote, Gloucester, *mentioning Control. Or on reply card, circle* **No 542.**

QUICK LOOKS

Silicon rectifiers. Available from International Rectifier is a range of diffused-junction devices which will provide output currents up to 1·8A mounted on a heat sink, or 1·3A in air, over a peak-inverse-voltage range from 100 to 600V. Reverse leakage is given as 500μA at rated p.i.v. at 150°C All rectifiers in the range have operating temperature limits of −65 to +175°C.

For more information write to: International Rectifier (G B.) Ltd, Hurst Green, Oxted, Surrey, *mentioning Control. Or on reply card, circle* **No 522.**

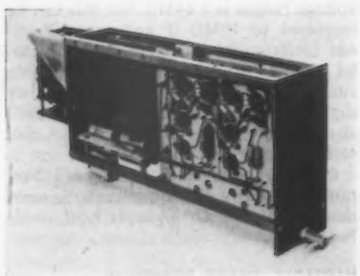
Low voltage supplies. Three ranges from J. Langham Thompson, with ratings of 20, 30, and 60VA, can be mounted in groups of five, four, or three units respectively behind standard 19in panels. Full overload and short-circuit protection is fitted, and the 30 and 60VA units use double-regulator techniques to improve regulation and efficiency. Fixed voltages from 6 to 60V can be provided at currents determined by the maximum VA rating.

For more information write to: J. Langham Thompson Ltd, 176 High Rd, Bushey Heath, Herts., *mentioning Control. Or on reply card, circle* **No 523.**

Oscilloscope. Kasama Electronics' model 256 oscilloscope is claimed to have a measurement accuracy of ±2% on time-base and *y*-amplifier, the latter ranging from 25mV/cm to 100V/cm with a constant band-width of d.c. to 11Mc/s. An internal pre-amplifier can increase the sensitivity to 2·5mV/cm over a band-width of 5 c/s to 700 kc/s. Time-base range, using an *x*-axis amplifier with a gain variable from 1 to 10, is 0·05μs/cm to 200ms/cm.

For more information write to: Kasama Electronics Ltd, 139–149 Fonthill Rd, London, N.4, *mentioning Control. Or on reply card, circle* **No 502.**

Stabilized power supply. A unit by Experitron provides two 300V, 200mA d.c. outputs, stabilized to ±0·2% from zero to full load. It will cope with input-voltage fluctuations of up to ±5%, and maximum noise and ripple in the output is 15mV. A preset voltage-control on each output allows minor variation, but the units may also be supplied with controls giving a range from 200 to 300V. Dimensions are 6 × 3½ × 15½in, and



design is such that five supplies may be mounted in a standard 19in rack; power supply required is 200–240V, 50 c/s.

For more information write to: Experitron, 165 Young St, Sheffield, 1, *mentioning Control. Or on reply card, circle* **No 501.**

Locked-ratio frequency multiplier. Langham Thompson's type 702 frequency multiplier is intended to overcome difficulties in measuring audio and sub-audio frequencies due to the necessarily long count-time. The basis of the multiplier is a special cathode-ray tube with a ten-spoke metal target between deflector-plates and screen. Each cycle of the incoming signal generates a circular trace from which ten output-pulses are derived as the beam is interrupted.

For more information write to: J. Langham Thompson Ltd, 176 High Road, Bushey Heath, Herts., *mentioning Control. Or on reply card, circle* **No 537.**

Constant-weight feeder. The Sinex Minor, intended for applications requiring an accurately controlled low-output feed, will deliver any dry powder or granular material at a rate between 2 and 15 kilograms/h; accuracy is ±1%. The unit comprises a small buffer hopper, a vibratory feeder, and a weighing belt assembly

incorporating a high-speed balance and all necessary control circuits.

For more information write to: Sinex Engineering Co. Ltd, North Feltham Trading Estate, Feltham, Middx, *mentioning Control. Or on reply card, circle* **No 532.**

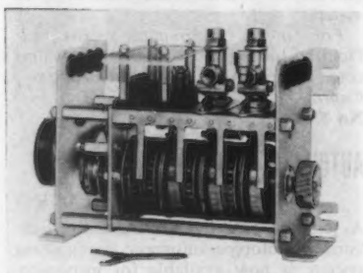
Soldering tweezers. An instrument by Greenwood Electronic is intended for precise soldering of micro-miniature modules, solid-state devices, and other heat-sensitive components. The tweezers have ⅛in tips, both tips having heating elements. Operating from a 6V supply, the tip temperature is up to 554°F.

For more information write to: W. Greenwood Electronic Ltd, 677 Finchley Rd, London, N.W.2, *mentioning Control. Or on reply card, circle* **No 510.**

Level controller. The Simcar radiation switch, designed by Simon-Carves, is made by A. M. Lock. The gamma-radiation detector uses a transistorized encapsulated amplifier, housed either in a dust-proof or a certified flame-proof case. The source holders used have facilities for switching the radiation off when necessary.

For more information write to: A. M. Lock & Co. Ltd, Prudential Buildings, Oldham, Lancs., *mentioning Control. Or on reply card, circle* **No 527.**

Sequence timer. Rodene Electrical's Magnacam timer will directly control air-cylinders and/or electrical equipment. Valves and switches are individually interchangeable and replaceable. The valves are three-way units with ¼in bores suitable for use at pressures up to 80 lbf/in^2; the switches are s.p.d.t. units rated for currents up to 15A. Up to 24



pairs of cams can be fitted, and camshaft speed-range is from 1 rev/(number of cams × 7s) to about 1rev/week.

For more information write to: D. Robinson and Co. Ltd, 5–7 Church Rd, Richmond, Surrey, *mentioning Control. Or on reply card, circle* **No 539.**

Relays. Available from L. E. Simmonds is a range of relays made by A. le Boeuf et Fils (France). The SB21 is a typical relay in the range, for which coils are available for operating at currents between 1μA (21kΩ coil) and 10mA (0·3Ω coil). Coils may also be double-wound, for differential deflexion, and this type may also have a logarithmic law so that currents are multiplied together or divided one into another.

For more information write to: L. E.

New for the user

Simmonds Ltd, Byron Rd, Harrow, Middx, *mentioning Control. Or on reply card, circle* **No 528.**

Automatic tension control. A system by Hydraulic Machinery Drives may be used on any kind of web (including extensible plastics) where the main drive is hydraulic. Tension is controlled to within ±0·25 ounces per inch width, and the preset tension may be adjusted while the machine is running.

For more information write to: Hydraulic Machinery Drives Ltd, 101 London Rd, Reading, Berks., *mentioning Control. Or on reply card, circle* **No 521.**

Plug-in relay. A two-pole change-over relay by Dewhurst has an International Octal plug-in base. Normally supplied with coils for either 24 or 220V a.c. operation, coils for other voltages are readily available. Operating speed may be up to 3600 per hour, and the solid silver contacts have a life-expectancy of

over 10^7 operations with normal switching capacity of 6A, 250V a.c. or 2A, 400V a.c.

For more information write to: Dewhurst & Partner Ltd, Inverness Wks, Hounslow, Middx, *mentioning Control. Or on reply card, circle* **No 541.**

Flame detectors. Ultra-violet-sensitive detectors by Elcontrol are designed for flame-detection systems. The UV1 is for use on flames with a large amout of modulated u v. light, and the UV2 for use where greater discrimination is required e.g. multi-burner installations and very steady flames). These cells are responsive at temperatures up to 90°C, and do not fail catastrophically even at that temperature.

For more information write to: Elcontrol Ltd, Wilbury Way, Hitchin, Herts., *mentioning Control. Or on reply card, circle* **No 534.**

Delay lines. Cossor Radar's range of magnetostriction delay-lines has now been extended to allow dynamic storage of pulsed information for periods from 5μs to 1·5ms. The complete delay lines can be supplied mounted in metal containers which protect the coil and provide a shield between the line and adjacent circuits.

For more information write to: Cossor Radar & Electronics Ltd, The Pinnacles, Harlow, Essex, *mentioning Control. Or on reply card, circle* **No 513.**

PUBLICATIONS RECEIVED

The collected work of John von Neumann, Volume 1 *by* **A. H. Taub.** *Pergamon Press. 1961. 664 pp. £4 4s 0d.* ★557

An introduction to linear network analysis *by* **P. S. Farago.** *The English Universities Press Ltd. 1961. 336 pp. £1 10s 0d.* ★558

Electromechanical components for servomechanisms *by* **Davis** *and* **Ledgerwood.** *McGraw-Hill. 1961. 338 pp. £4 9s 0d.* ★559

Risley supplement to the Manchester University autocode manual *by* **B. E. Roberts.** *U.K.A.E.A. 1961. 10 pp. 1s 9d.* ★560

Synthesis of optimum control systems *by* **Sheldon S. L. Chang.** *McGraw-Hill. 1961. 382 pp. £4 11s 0d.* ★561

Physics for electrical engineers *by* **W. P. Jolly.** *The English Universities Press Ltd. 1961. 308 pp. £1 1s 0d.* ★562

Gasentladungsröhren Wirkungsweise und Andwendung *by* **Norbert Kirchner.** *R. v. Decker's Verlag—G. Schenck. 1961. 124 pp.* ★563

Pig 3—a simple compiler for Mercury *by* **D. C. Bindon.** *U.K.A.E.A.—Reactor Group. 1961. 9 pp. 2s 6d.* ★564

The Omegatron* *by* **P. G. Bentley** *and* **J. Leece.** *U.K.A.E.A.—Development and Engineering Group. 1961. 22 pp. 4s.* (**DEG Report 327 (CA)*) ★565

An algorithm for translating chemical names to molecular formulas *by* **Eugene Garfield.** *Institute for Scientific Information. 1961. 78 pp. $5.00.* ★566

Miniaturization *edited by* **H. D. Gilbert.** *Reinhold Publishing Corp. 1961. 316 pp. £4 0s 0d.* ★567

An approach to Cybernetics *by* **Gordon Pask.** *Hutchinson and Company. 1961. 128 pp. 12s 6d.* ★568

Design manual for transistor circuits *by* **J. H. Carroll.** *McGraw-Hill. 1961. 392 pp. £3 14s 0d.* ★569

Amendments to the thirteenth edition of the Regulations for the Electrical Equipment of Buildings. *The Institution of Electrical Engineers. 1961. 40 pp. 2s 6d.* ★570

A mercury program for the solution of simultaneous first-order total differential equations of basically linear form *by* **B. E. Roberts.** *U.K.A.E.A. 1961. 26 pp. 2s 6d.* ★571

Network for the Nation *by* **G. B. Jackson.** *Central Electricity Generating Board. 1961. 32 pp.* ★572

A summary of the Annual Report for 1960–61. *Central Electricity Generating Board. 1961. 24 pp.* ★573

Safety and health in industry *designed and compiled by* **Transworld News Service.** *Sky Press Ltd. 1961. 152 pp.* ★574

Computer. I.C.T.'s 558 punched-card data-processing system is the subject of an illustrated booklet. ★575

'Precision Control in Chemical Feeding', from Wallace & Tiernan, describes a wide variety of controllers and feeders. (Publication S/109). ★576

Instruments, for temperature, pressure and humidity, are detailed in List 99 from Cambridge Instrument. ★577

Miniature primary elements for pH and Redox measurement are shown in publication 158 from Kent. ★578

'Industrial furnaces and equipment' is the title of leaflet V70 from Incandescent Heat. ★579

Resistance-network analogue: leaflet No. 115 from Bruce Peebles describes this equipment. ★580

'Recording pyrometers and resistance thermometers' is the title of illustrated brochure E/19/1 from Negretti and Zambra. ★581

Wide-band oscilloscope. The WM16 is the subject of E.M.I.'s illustrated leaflet. ★582

Hose. Terylene-reinforced industrial hose is described in a booklet from I.C.I. ★583

Industrial hydraulics. Armstrong's 41-page manual lists a wide range of hydraulic units. ★584

Data processing. A booklet from I.C.T. tells how progress in Scotland has been assisted by data processing. ★585

Centralized temperature indication is the subject of publication No APP/26 from Negretti and Zambra. ★586

Lighting applications using electroluminescence are the subject of a leaflet from Thorn Electrical. ★587

'Ion Exchange Progress.' The first number of a technical news sheet from Elga Products. ★588

Saturable reactors using C-cores are the subject of a pamphlet from Electro Methods. ★589

Polarograph. Evershed's mk 200 polarograph is described in an illustrated leaflet, publication No 373. ★590

Chassis nests, for mounting plug-in chassis, one described in a leaflet from Bruce Peebles. ★591

Instrumentation by Hartons is the subject of a recent illustrated booklet. ★592

Card pur cher. Account-Token's Vari-punch, for key-punching of tab cards directly at source, is described in a recent leaflet. ★593

Ratio transformers by Gertsch (U.S.A.) are shown in Catalogue No. 6 from Wayne Kerr. ★594

Ceramic valveholders by Plessey are fully described in Publication No. 387. ★595

Transportable tape-recorder. E.M.I.'s RE301 recorder is the subject of an eight-page leaflet. ★596

Teleprinters by Creed are described in an illustrated leaflet. ★598

Position control. The Emicon B100 position control for machine tools is the subject of a comprehensive booklet from E.M.I. Electronics. ★599

'Electric-furnace fume control' is the title of a leaflet describing equipment by Tilghman's. ★600

★ Circle the relevant number on the reply card facing page 162 for further information

Book Reviews

Flowmeters

Flow Meter Engineering Handbook, *published by Minneapolis–Honeywell Regulator Company. 1961. 170 pp. £2 15.*

The handbook presents the theory and practice of flow measurement by pressure-drop methods in a straightforward manner, but is written around the instruments produced by the Minneapolis–Honeywell Regulator Company.

The book begins with a discussion of the types of primary flow elements and then proceeds to outline their various applications, followed by section detailing methods of installation.

Three chapters are then devoted each to a detailed study of a particular orifice calculation, from an approximation check to a precise calculation. Each stage of the argument is clearly explained and well illustrated with tables and charts. Subsequent chapters deal with the derivation of the constants for devices other than concentric-orifice plates, and the derivation of formulae and working equations used in the examples. An extensive chapter of tables and curves is included, giving all the factors and physical data for calculating orifice sizes.

It is a well written and illustrated handbook but it is marred by a number of arithmetical errors in the introductory sections to some chapters, by the presentation of tables with no information as to their origin, and by the incorrect heading to page 33.

A. B. TAVENDALE

Management

The business of management, art or craft? *by* **Roger Falk, O.B.E.** *Penguin Books Ltd. 1961. 251 pp. 3s. 6d.*

This is a Pelican, and therefore it is not surprising to find that the very first statement in it is: 'This book is neither a manual nor a textbook'. The Pelican series frequently puts forward views on or descriptions of special subjects which are for the educated layman's interest, and naturally these have a certain attraction for the specialist in the subjects as well. The merit of Roger Falk's book is more marked in the matter of views than of description, as it gives an impression of a soliloquy, a musing on experience and expectation in the field of management. The style of writing is free, even colloquial, which, while it supports the impression, does not make the descriptive aspect emphatic and sharp. Sometimes technical terms, such as 'functional specialists', are used without definition, so that the reader new to the subject should perhaps attempt more elementary treatments before he turns to this book.

The author states his views and his findings as a manager in pungent terms, as when he says that the only management lesson he has learned 'is that management "rules" must always be subordinated to wider, human issues'. He thinks that much writing on management is out-of-date, and by his book hopes to help those who feel the subject is worth thinking about.

The book proceeds with chapters on the *Business of Business, of Management,* with thoughts on *Management or Leadership —or Both* interleaved. Falk's main love of marketing and its problems is often evident—'customer creation' is his term. He has to say of automation that it is not a soulless monster as confused thinking suggests, but 'rather, a conception of how work should be organized', work covering the whole business of business. This is good, but one is next confronted with: '. . . essentially automation (which really symbolizes the new technology) pays little attention either to skills or to the product or service to be economically supplied'. He goes on to say: 'It takes far more notice of the undeniable fact that there are discernible *patterns* in most happenings', and whilst the pertinence of this remark is refreshing, its predecessor seems to be both faulty and out of place. The management problems raised by automation appear several times in the book as a main topic, but usually referred to in the guise of the effects of inevitable technological advance. He says that nowadays 'very few management tasks do not call for a general understanding of technological operations . . . how far should technical knowledge qualify for high management responsibility . . . ?' We are, typically for this book, not given a categoric answer to this hoary problem, but as consolation there is such an observation as upon the dangers of management becoming cocooned in its know-how.

Apt quotations from other writers occur throughout the book, my favourite being from 'The Boss: the Life and Times of the British Business Man' by Roy Lewis and Rosemary Stewart in the chapter *Management for Whom*? This chapter ends with a really provocative questioning of the ideological significance of the subject it has sought to discuss, and one would like to see this debate taken much further, as Falk indicates it can be.

Management of What? says *inter alia* that this is an accountant-ridden age, and gives a brilliant thumb-nail sketch of the rise, flowering and deflowering of a typical but fictional small family business in these days. This stage in the book seems the first wide-scale use of case material from real industrial life in Dexion Ltd, and this is followed by a long reference to the Wedgwood story in the chapter *Family Firms.* Next, getting the best from people and the training of managers are discussed, and under the latter the point is made that the primary need of training is to provide for the succession in control of the enterprise, a provision often overlooked.

The book ends with some case studies in detail of successful management in some named firms and of failure in some anonymous ones. These chapters are fascinating and worth reading for their own sake. The final chapter is an anticlimax —a fictional dialogue about future developments, which does not grip the reader with the feeling of realism that he should have, if only because it follows two chapters reporting reality. The message is that the manager tomorrow will be the catalyst . . . reducing the gap between the technicians and the non-technicians so that both will work in an atmosphere of maximum co-operation. A slight wince at the word 'catalyst'—won't the manager be changed, too?

G. M. E. WILLIAMS

Bearings

Instrument ball bearings *by* **P. J. Geary.** *British Scientific Instrument Research Association. 1961. 80 pp. £1 1s.*

On reading through this survey one quickly appreciates the excellent quality of the work. It is intended, as mentioned on the first page, to provide an outline of, and introduction to, the subject of instrument ball bearings, together with adequate references for those who require specialized information. Every aspect of the application of ball bearings to instruments is briefly but clearly explained, and this book will be of great assistance to all who are engaged in instrument design. Even the newcomer can understand the contents, and should be able to arrive at the best solution to his particular bearing problem. One very valuable feature is the logical method used by the author to introduce worth-while references to the appropriate literature and standards in each chapter. This has produced a book in which all the information is very orderly, and therefore straightforward to use—the hall-mark of a good reference book. This survey should certainly be on every instrument designer's bookshelf.

W. SAVAGE